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ENGINEERING:

An Illustrated Weekly Journal.

EDITED BY CHAS. COOPER AND J. FOSTER PETREE.

OFFICES FOR ADVERTISEMENTS AND PUBLICATION, 35 & 36, BEDFORD ST., STRAND, LONDON, W.C.2.

VOL. 164—No. 4253 *Registered at the General Post Office as a Newspaper* *LONDON: FRIDAY, AUGUST 1, 1947.* PRICE 1s. 6d. POSTAGE { INLAND 2½d. FOREIGN 3d.

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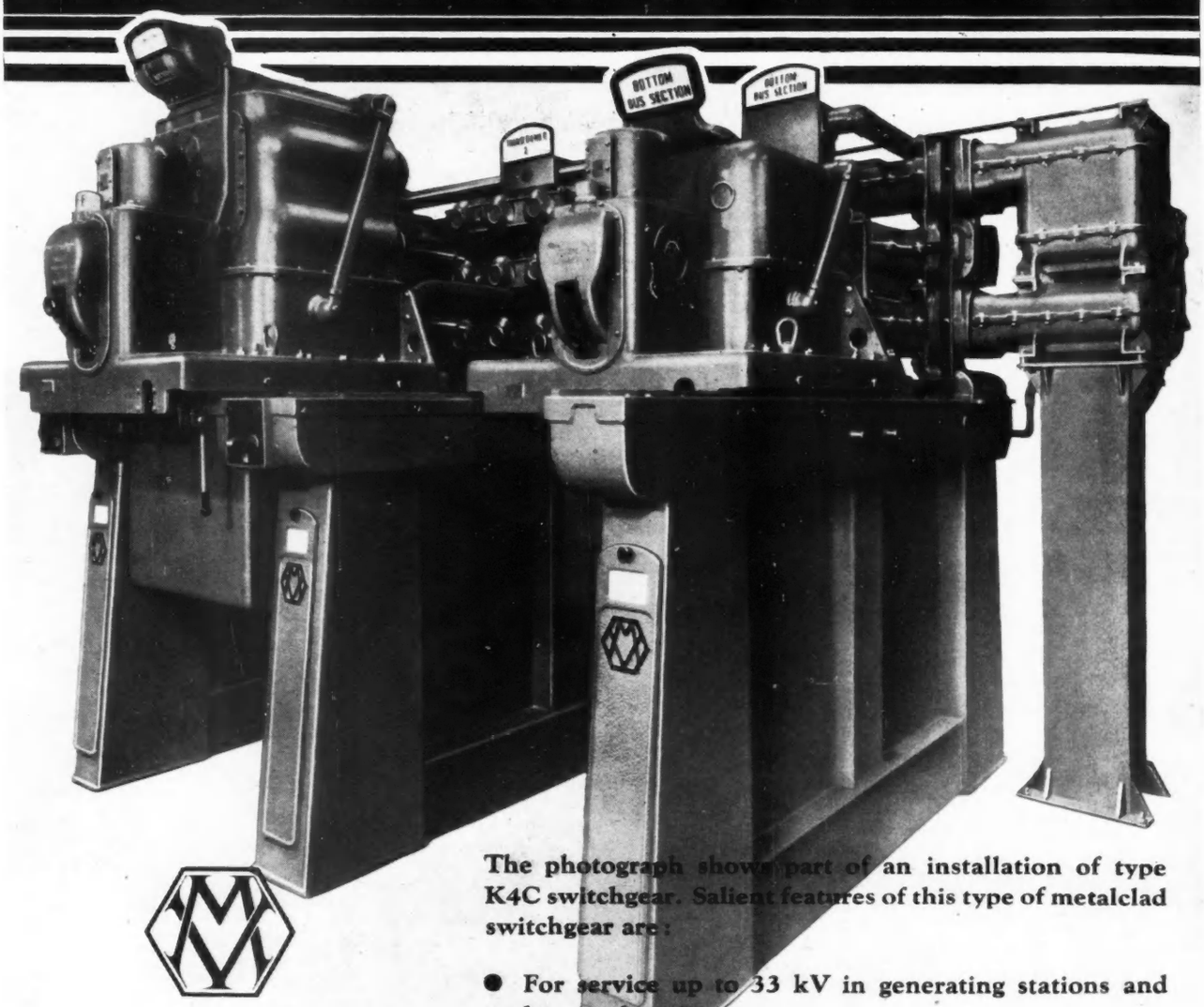

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INVESTIGATIONS ON DELAY-ACTION FUSES.*

By J. McKEOWN, D.Sc., M.I.Mech.E., F.I.M.

IN February, 1940, the British Non-Ferrous Metals Research Association was approached by the M.I.R. (c) department of the War Office for assistance in the development of a delay-action fuse mechanism operated by the creep, under the action of stress, of a small element of lead or lead alloy. The primary requirement of the War Office representatives was detailed information on the creep of lead and lead alloys under the action of torsional stresses. They envisaged using a short length of square-section lead alloy acted upon by a torque provided by a spring. When a predetermined amount of twist had occurred, electrical contacts in the mechanism would be closed, thus making a circuit from a small dry cell through an electric detonator.

Information of the type required did not exist and work was immediately undertaken to provide it. When this work had progressed sufficiently far, a few prototype delay-action fuses incorporating the suggested principle were constructed by M.I.R.(c) and tested. It was found that there was very bad correlation between the rate of torsional creep in the actual mechanism and that measured by ordinary torsional methods external to the mechanism. The difference in behaviour was clearly due to (1) excessive and non-reproducible friction in the moving parts of the mechanism; and (2) a variable torque imposed by the spring, this torque starting at a high value and falling off as release of the coiled up energy in the spring took place. Attempts were made by M.I.R. (c) to re-design the mechanism incorporating ball bearings so as to reduce, and, if possible, standardise the friction. It was also considered that, in practice, calibration of the lead in terms of time to produce a definite twist would have to be made using springs and in models of the mechanism. The introduction of ball bearings increased the size of the mechanism too much to make it useful from the military point of view, and ultimately the idea of using torsional creep was discarded in favour of direct tensile creep of a specimen of rod.

In this second form of mechanism, which later became known as Lead Delay No. 1, a 3-in. length of lead alloy was subjected to tensile loading by means of a compression spring. When a predetermined amount of creep had occurred, electrical contacts were closed, shorting a small dry cell through an electric detonator. Some of the previous work carried out by the Association on the creep of lead under tensile loading could be used in the original design of this mechanism, but for the final design it was necessary to carry out tests under actual spring-loading conditions, as under these conditions the load, and consequently the stress, in the lead rod varied with the extension of the rod. The chief difficulty experienced with Lead Delay No. 1 was in providing suitable means of gripping the ends of the lead rod so as to apply the load to it. All the mechanical methods of gripping tried were unsatisfactory as they gave rise to stress concentrations which produced localised creep. A method was developed of soldering the ends of the lead rod into small brass cylinders using a low melting point solder. While this method was found to be perfectly satisfactory when carried out under laboratory conditions, it was most unsatisfactory when tried out under mass-production conditions, and this form of fuse also had to be discarded. Attention was next turned to another method of deforming lead. This consisted of shearing through a small length of lead rod by a loop of fine steel piano wire. Under laboratory conditions this method gave very promising results, but it was finally rejected because the constructional tolerances of the whole mechanism were too small for quick mass production. In this mechanism it was proposed to load the steel loop by means of a tension spring, the spring carrying a striker which, when the loop had sheared through the lead, struck a small detonator cap.

The experience gained in the later two forms was combined to produce the final form known as the L Delay. In this final form a short length of lead alloy was machined so as to have a waist giving it a dumb-bell shape, thus concentrating the deformation which occurred under load. This concentration of deformation enabled another method of gripping the ends to be used successfully, this method consisting of pinning them to small brass cylinders by means of fine wire pins. The loading was again carried out by tension spring and again a striker attached to the live end of the spring was released by the breaking of the specimen and struck a detonator cap. This final form of the delay had an overall length of $4\frac{1}{16}$ in., including the cap and detonator holder, and a diameter of $\frac{3}{8}$ in.

The requirements of the delay action mechanism had been laid down by the General Staff as follows: (1) fuses should be capable of giving timings from half an hour up to 28 days; (2) at any one timing the reproducibility should be within the limits of $\pm 33\frac{1}{3}$ per cent.; (3) the effect of temperature on the time of operation of the fuse should be as small as possible and should be known.

The previous investigations carried out by the Association on creep of lead had been confined mainly to work at low stresses, such as produced relatively long lives in specimens of lead or lead alloys. It was considered at the outset that the

Fig. 1. TORSION TESTS. NO OVERSTRAIN

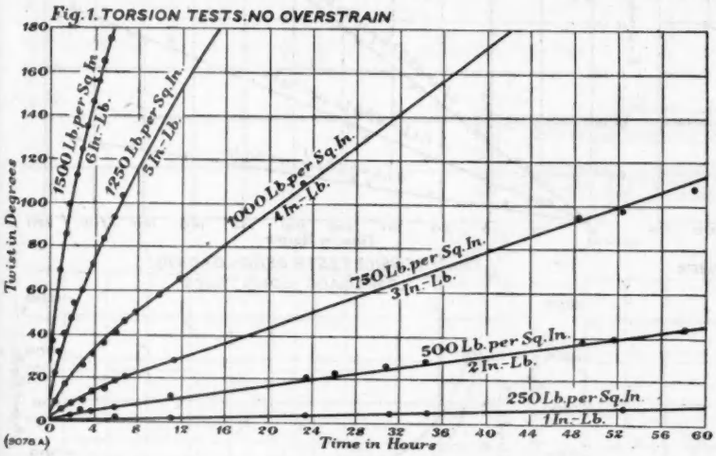

Twist in Degrees
Time in Hours
1500 Lb. per Sq. In. 6 In.-Lb.
1250 Lb. per Sq. In. 5 In.-Lb.
1000 Lb. per Sq. In. 4 In.-Lb.
750 Lb. per Sq. In. 3 In.-Lb.
500 Lb. per Sq. In. 2 In.-Lb.
250 Lb. per Sq. In. 1 In.-Lb.
(9078 A)

Fig. 2. TORSION TESTS. NO OVERSTRAIN

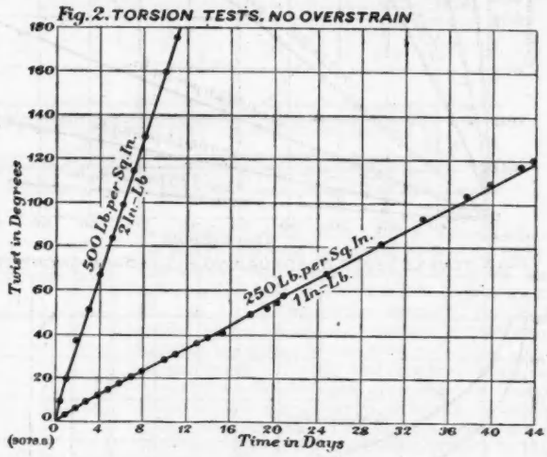


Fig. 3. TORSION TESTS. OVERSTRAINED 180 DEG.

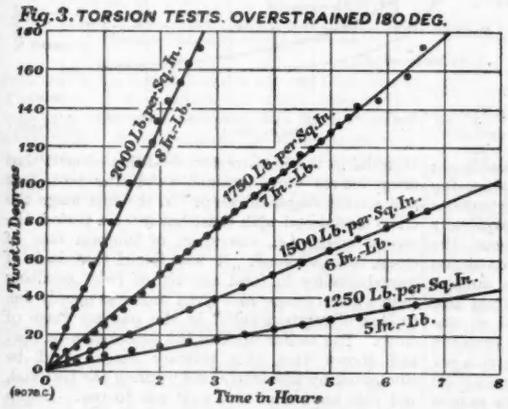

Twist in Degrees
Time in Hours
2000 Lb. per Sq. In. 8 In.-Lb.
1750 Lb. per Sq. In. 7 In.-Lb.
1500 Lb. per Sq. In. 6 In.-Lb.
1250 Lb. per Sq. In. 5 In.-Lb.
(9078 C)

Fig. 4. TORQUE-TIME CURVES. HIGH TORQUES-SHORT TIMES

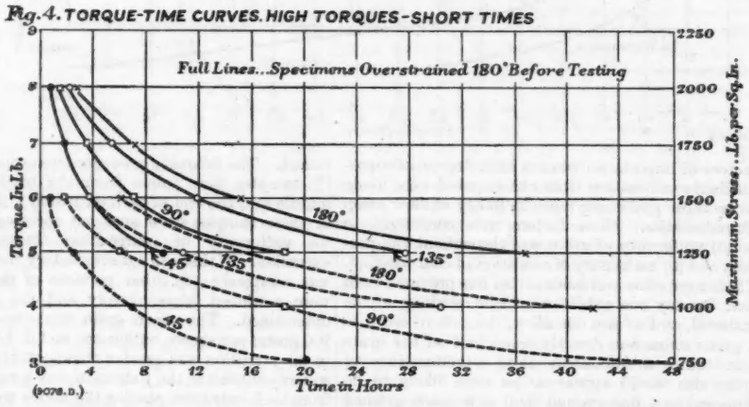
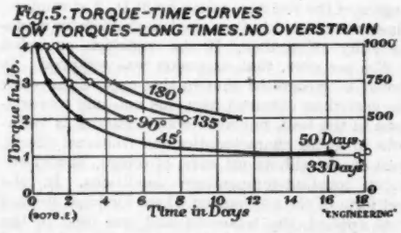


Fig. 5. TORQUE-TIME CURVES LOW TORQUES-LONG TIMES. NO OVERSTRAIN



* Communication from the British Non-Ferrous Metals Research Association.

INVESTIGATIONS ON DELAY-ACTION FUSES.

Fig. 6. TENSILE CREEP TESTS. DEAD-LOADING

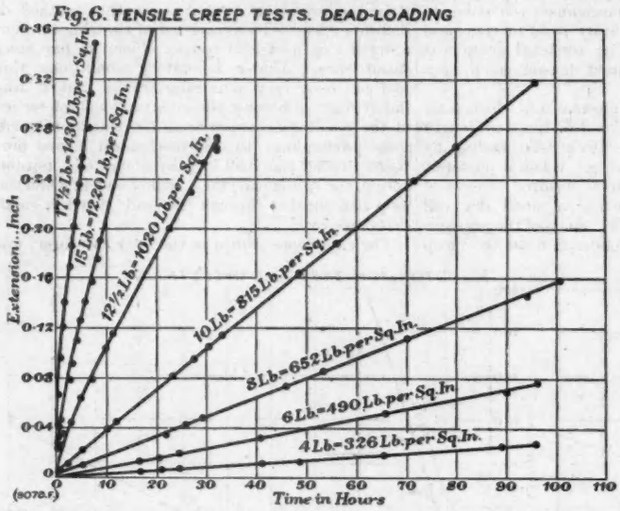

Extension...Inch
Time in Hours
(9078.F.)
17½ Lb.=1430 Lb. per Sq. In.
15 Lb.=1220 Lb. per Sq. In.
12½ Lb.=1020 Lb. per Sq. In.
10 Lb.=815 Lb. per Sq. In.
8 Lb.=652 Lb. per Sq. In.
6 Lb.=490 Lb. per Sq. In.
4 Lb.=326 Lb. per Sq. In.

Fig. 7. TENSILE CREEP TESTS. DEAD-LOADING

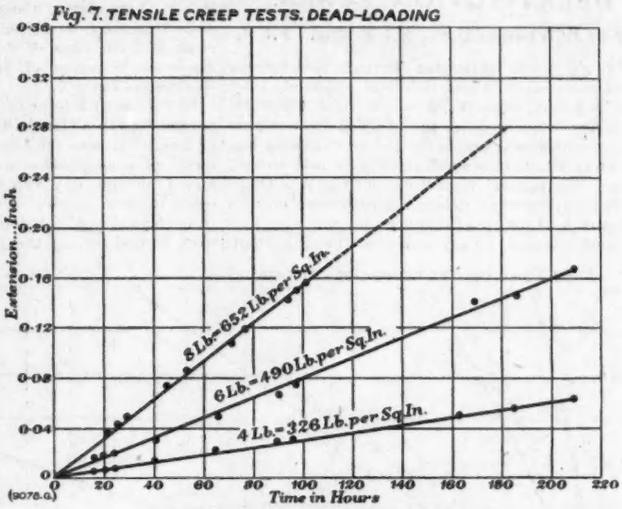


Fig. 8. TENSILE TESTS. DEAD-LOADING. HIGH LOADS—SHORT TIMES

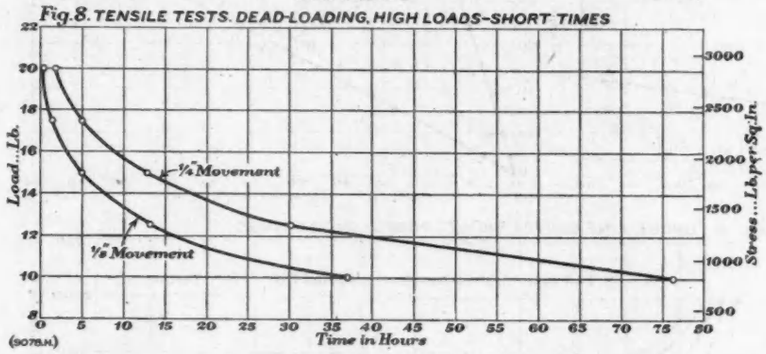
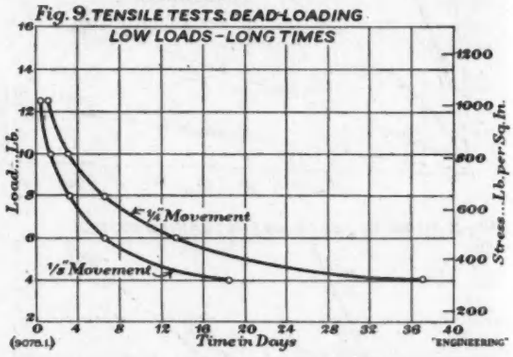


Fig. 9. TENSILE TESTS. DEAD-LOADING LOW LOADS—LONG TIMES



factors of importance when a high degree of reproducibility of breaking time was required were likely to be those governing reproducibility of slow creep characteristics. These factors were considered to be (*a*) uniformity of grain size throughout the product and (*b*) uniformity of condition of cold working. There were clear indications from our previous work that for any one condition of cold working of the material, and in any one alloy, the rate of creep at a given stress was directly dependent on the grain size. Since a sufficiently close reproducibility of grain size would appear to be more likely to be obtained in a fine-grained than in a coarse-grained material it was decided to concentrate on a lead alloy of very fine grain size. The Association's previous work suggested the use of tellurium lead, extruded fairly cold and subsequently heat treated at a temperature sufficiently high to produce a structure stable at ordinary temperatures over long periods of time of storage, but not so high as to produce recrystallisation and grain growth. These requirements were selected on somewhat inadequate information, and it is interesting to note that further experimental investigations carried out at a later date showed that the conditions first selected were, in fact, the most suitable ones.

All supplies of tellurium lead used throughout the work were made from Broken Hill lead with the addition of 0·05 per cent. tellurium. Some hundreds of separate extrusions were made in a press the container of which was kept at 100 deg. C. ± 5 deg. C. throughout the extrusion. To avoid irregular cold work the materials were extruded in straight lengths and, after such local straightening as was necessary, were annealed for three hours at 100 deg. C., to stabilise the structure, and slowly cooled. Even under these carefully controlled production conditions it was not found possible to produce exactly uniform characteristics from one extrusion to the next and, in consequence, each extrusion had to be considered as an individual batch of material and its complete characteristics determined. The following procedure was standardised: (1) samples were taken from the beginning, the middle and the end of each extrusion; (2) portions of these samples were analysed spectrographically for uniformity of composition throughout the extrusion. If this was not satisfactory the extrusion was scrapped; (3) other portions of the samples were sectioned longitudinally and the grain size determined. The mean grain size aimed at was 900 grains per square millimetre, and if the variation in an extrusion was greater than ± 200 grains per square millimetre the extrusion was scrapped; (4) from each extrusion passing the above tests sample lengths of the rod were taken by M.D.1* at random. These were tested in the actual mechanism for reproducibility of timing. If the variation exceeded ± 33⅓ per cent. that extrusion was scrapped. It should be recognised that in this part of the work the variations obtained were due not only to variations in the lead, but also to such factors as variations in spring characteristics and frictional effects. Such check calibrations were, of course, carried out under constant-temperature conditions. In the first form of the mechanism where torsional stresses were applied, the tellurium lead was used in the form of square-section rod of ¼ in. side. In Lead Delay No. 1, in which a compression spring applied a tensile stress, ¼-in. diameter rod was used, while in the final form, the L Delay, the material was obtained in the form of ⅛-in. diameter rod and the small dumb-bell units machined from it.

For the torsional creep tests in connection with the torsion-type delay, small machines were built in which one end of a short length of the square-section rod was gripped while the other end had a torque applied to it through a grip carried in a ball race. The spindle applying the torque carried a protractor, and a pointer attached to the frame of the machine enabled the twist to be read to an accuracy of ± ½ deg. The early tests on the material in the heat-treated condition showed that creep curves were obtained exhibiting both first and second stages of creep. In the first stage the creep diminished with time, but after a period, the second stage, *i.e.*, the stage of uniform rate of creep, was attained. It was found that lack of reproducibility in total amount of twist resulting from a given torque in a given time was mainly due to lack of reproducibility in the primary stage of creep. The earlier work of the Association on lead had shown that this primary stage could be eliminated by previously cold working the material, and this knowledge was now put to use. Before commencing a torsional-creep test, specimens were twisted through 180 deg., and this resulted in tests in which only the second stage of creep was shown; thus a higher degree of reproducibility was obtained. Some of the earlier results obtained on material 0·268 in. square with a mean grain area of 1,000 grains per square millimetre are given in Figs. 1 to 5, on page 97. All these tests were made on square-section tellurium lead at a temperature of 20 deg. C.; the square was of 0·268 in. side; and the length of the specimen between the grips was 2 in. Figs. 1 and 2 give the creep curves obtained on the material in the condition as extruded, followed by annealing for 3 hours at 100 deg. C. and slow cooling. The first stage of creep is present in all the curves and is most clearly shown at 5, 4 and 3 in.-lb. torque. Results obtained on specimens of the heat-treated material overstrained 180 deg. before testing are given in Fig. 3, and in these cases no initial stage of decreasing rate of creep is present. The curves all pass through a point corresponding to a twist of about 2 deg., and this was due to a small amount of backlash in the machine. In Figs. 4 and 5, the curves of torque and time are given for twists of 45, 90, 135 and 180 deg., Fig. 4 giving results obtained with high torques and short times, and Fig. 5 results for low torques and long times. At low torques, the tests were run for at least 50 days, although the times of greatest

* M.I.R. (c) has now been renamed M.D.1.

INVESTIGATIONS ON DELAY-ACTION FUSES.

Fig. 10. TENSILE TESTS DEAD-LOADING HIGH LOADS-SHORT TIMES

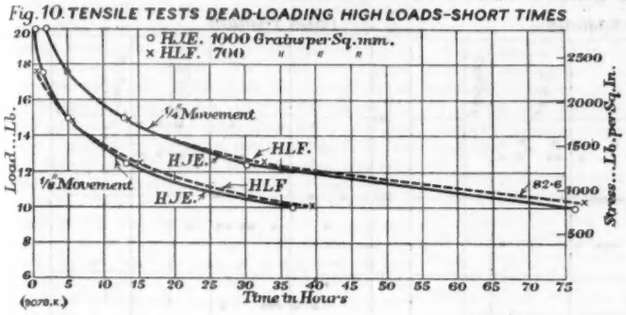


Fig. 11. TENSILE TESTS. DEAD-LOADING LOW LOADS-LONG TIMES

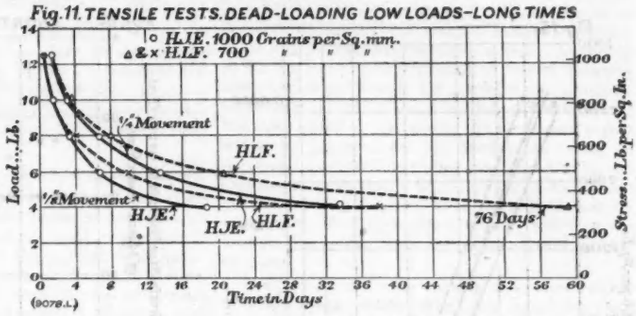


Fig. 12.

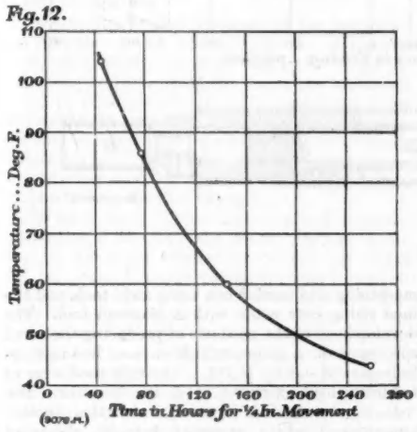


Fig. 13.

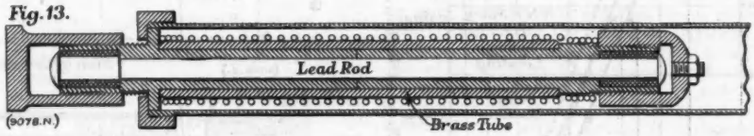
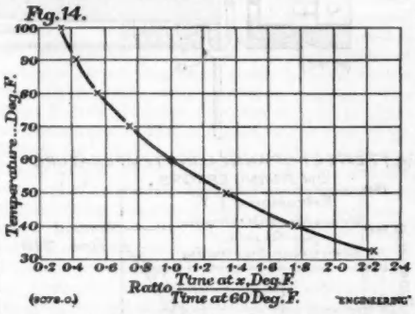


Fig. 14.



interest for the specific inquiry were up to 48 hours. The stress in a square-section shaft subjected to torsion is somewhat complex, and for a detailed examination of the problem the reader is referred to Todhunter and Pearson's *History of the Theory of Elasticity*. The problem was investigated by St. Venant, who gave the following formula:

$$T = 0{\cdot}208\, x^3 f_s,$$

where T = torque in in.-lb., x = side of square section in inches, and f_s = maximum shear stress in lb. per square inch, which occurs at the centre of the side of the square. When the side of the square = 0·268 in., a torque of 1 in.-lb. gives a stress of 250 lb. per square inch.

The application of the overstrain in the actual mechanism was found to be difficult and use of this idea had to be discarded. Reproducibility in the torque tests was, however, of a high order in overstrained material; thus with a torque of 5 in.-lb. the actual times for a twist of 90 deg. in five specimens were 350, 348, 344, 340, 337 minutes, the maximum difference being only 3·8 per cent. of the mean value.

Tensile creep tests on Lead Delay No. 1 were made on lengths of ½-in. diameter tellurium-lead rod, the early tests being made using dead loading. A considerable amount of work was done in arriving at a suitable method of gripping the ends of the lead rod. The one finally chosen consisted of passing the ends of the rod through a tightly fitting hole in the bottom of a small brass cylinder and casting into the space between the lead rod and the cylinder walls the ternary alloy 60 per cent. Bi, 20 per cent. Sn, 20 per cent. Pb, which has a melting point of about 110 deg. C. This operation had to be carried out without any flux because of the danger of corrosion resulting from flux residues. The ends of the lead rod were lightly scraped with a razor blade immediately prior to the casting operation, for which a bottom-pouring method was used to avoid inclusions of dross. The use of a glass tube, like a fountain-pen filler or eye dropper, was found to be successful, provided the whole operation was carried out quickly.

The results of dead-loading creep tests at 20 deg. C. on samples of the ½-in. diam. tellurium-lead rods are given in Figs. 6 to 9, opposite. In these tests the material used had been annealed previously for 3 hours at 100 deg. C. and slowly cooled. It will be noticed from Fig. 6 that the initial stage of decreasing rate of creep is shown in most of the curves. The relationship between the load and the time to produce movements ¼ in. and ½ in. are shown in Figs. 8 and 9. In Figs. 10 and 11, on this page, two materials from different extrusions are compared, one having a grain size of 700 and the other 1,000 grains per square millimetre. It will be noted from both Figs. 10 and 11 that the coarser-grained material took a longer time to give a predetermined movement at any one stress than the fine-grained material. This is particularly noticeable at the low loads and longer times. This is, of course, in conformity with the previous findings in the Association's work that in lead and lead alloys at low stresses a coarse-grained material creeps less than a fine-grained material. It also indicates the necessity for accurate control of grain size, but when all possible has been done in this direction it has proved to be necessary to consider each extrusion as a separate material requiring separate calibration for the determination of the relationship between time and the amount of creep.

The effect of temperature on timing was investigated for specimens of the material H M X, using a mean spring load of 11 lb. 1 oz. The results obtained are shown in Fig. 12. It is considered that a similar type of curve would hold for other extrusions of the tellurium lead, and making this assumption the curve shown in Fig. 14 has been plotted. This curve was used to predict the timing that would be given by delays operating at temperatures other than the calibration temperature. For example, if a certain load is required to give a time of 10 days at 60 deg. F., at 100 deg. F., the same load would give a time of 0·31 × 10 = 3·1 days, and at 32 deg. F. the same load would give a time of 2·21 × 10 = 22·1 days. This shows that for a total change in temperature from 32 deg. to 100 deg. the change in time of action of the delay is approximately 7 : 1.

When the calibrations of lead rod were carried out under spring loading conditions, considerable variations in timing were obtained initially and these were traced to (*a*) changes in the load-deflection characteristics of the springs and (*b*) non-reproducible friction effects in the moving parts of the delay. The former trouble was overcome by giving the springs a final heat-treatment of 5 to 10 minutes at 250 deg. C. In production assembly, the load applied by the spring was measured indirectly by inserting the spring in the delay to a fixed compressed length. In order that the load should be applied to a sufficient degree of accuracy, the loaded length of each spring had to be known to within $\frac{1}{10}$-in. This was done by grading the springs under conditions reproducing the friction present in the assembly. The non-reproducible friction observed in the early tests was traced to faulty machining of components and was overcome by using hard-drawn brass tube (see Fig. 13) with a tolerance on the bore of ± 0·002 in. and reducing the machining tolerance on the brass spigots to ± 0·0005 in.

As mentioned earlier, while the method of gripping the ends of the lead rods by casting the low melting-point solder on them was quite successfully used under laboratory conditions, it was not so successful under the conditions of mass production. Tests on fuses taken from the production line showed a much greater variation in timing than had been found in the laboratory and an examination of the faulty units revealed that two main types of fault existed: (1) the solder had failed to wet the lead rod over the requisite end length, which resulted in a long gauge length and consequently a shorter time of action of the fuse; (2) the solder had leaked between the brass end piece and the lead rod, run down the latter, and decreased the acting length, or increased the friction between the lead rod and the surrounding brass tube, both of these giving a longer time of action of the fuse. While attempts were being made to overcome the above defects in design, as shown by the failure of mass-production methods to reproduce laboratory results, the third form of delay was successfully developed and, as it had so many advantages over the other forms, production of the earlier types was suspended and was not, in fact, recommended during the war.

The delays previously described suffered from various defects in their action, but the most serious defect from the military point of view was the size of a complete unit. In addition, the effect of temperature was so considerable that it was necessary to provide some method of setting the timing to compensate for this. It was envisaged that this could be provided in the delay depending for its action on creep in torsion by varying the position of the fixed electrical contact relative to the moving contact—separating them more for operation at higher temperatures and bringing them closer for lower temperatures than the calibration temperature. In the delay which depended for its action on creep in tension the four shims placed between the fixed and moving contacts provided three different timings and these could be utilised to compensate for temperature effects on the rate of creep, i.e., time of action of the delay.

In conjunction with M.D.1, intensive consideration

INVESTIGATIONS ON DELAY-ACTION FUSES.

Fig. 15.

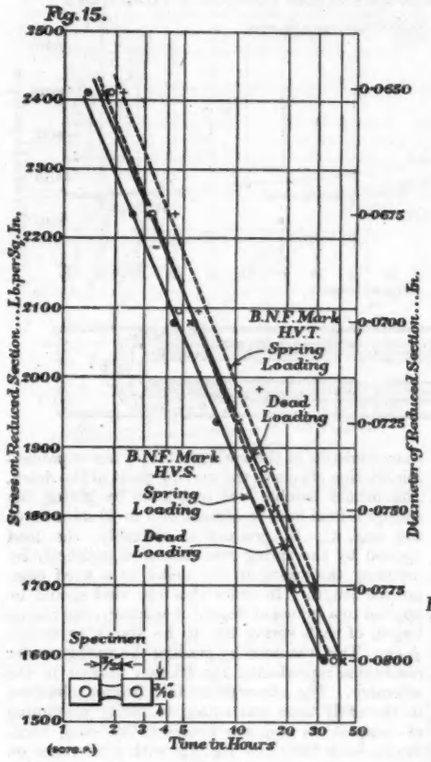


Fig. 16. SHORT TIMINGS LONG TIMINGS

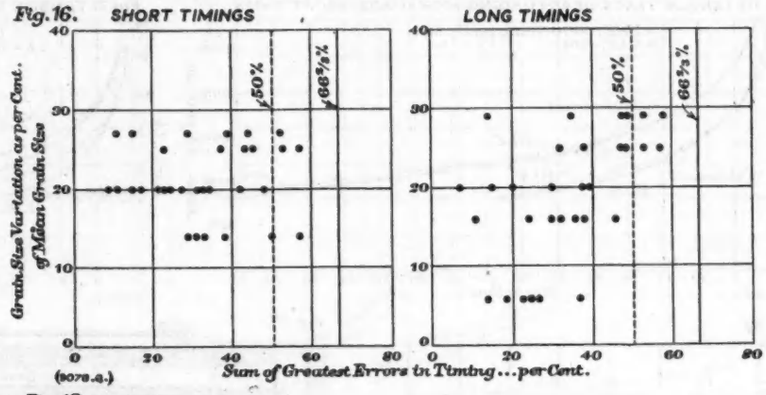


Fig. 18.

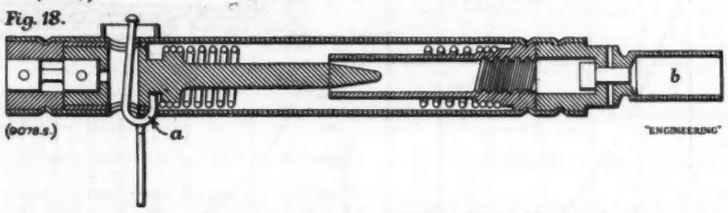
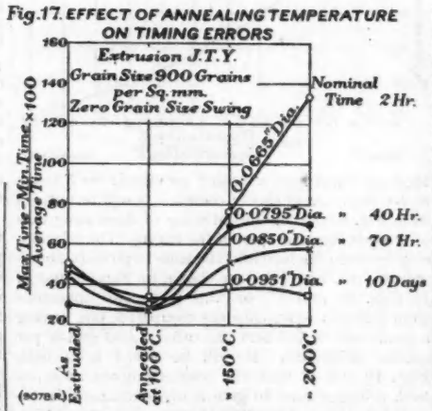


Fig. 17. EFFECT OF ANNEALING TEMPERATURE ON TIMING ERRORS



was given to the possibility of providing a much smaller unit and the following points were thought to be important: (1) the complete delay should have a size not exceeding that of the average fountain pen, this being a particular requirement for the possible use of the delay in sabotage operations; (2) with a small size unit it would be possible to provide a number giving different timings, these to be supplied in a wallet-like container, and these different timings would enable allowance to be made for the actual temperature of use differing from the temperature at which the nominal time of the delay was determined; (3) the action of the delay should be such that the provision of an electrical battery could be dispensed with, in other words, the mechanisms should be purely mechanical and not depend on the closing of an electrical circuit; (4) it was thought that greater reliability would result from the use of tension springs instead of compression springs, as friction effects could more readily be avoided.

TABLE I.

Extrusion No.	BNF Mark.	Grain Size, Grains per sq. mm.	Variation, ± Percentage of Mean.
1	HVR	600–1,000	25
3	HVS	600–1,000	25
4	HVT	600–800	14
5	HVU	600–800	20
6	HVV	600–900	20
7	HVW	400–700	27
17	HXP	600–900	20
18	HXR	600–1,100	29
20	HXS	800–1,100	16
21	HXT	800–900	6
24	HZK	700–1,000	18
25	HZL	600–800	14
27	HZN	600–1,000	25
28	HZO	600–900	20
29	JBJ	600–800	14

To meet the above requirements, it appeared that the most suitable arrangement would be to load a short length of lead in tension and when it broke the release of the remaining energy in the spring could be utilised to operate a striker hitting a detonator cap. In order to overcome the difficulty of securing the ends of the length of lead rod it was clear that the stress and strain in the lead would have to be concentrated away from the grips. This could be done only by reducing the cross-section of the lead by machining, and as a result of experiment the small specimen of tellurium-lead shown in the bottom left hand corner of Fig. 15 was decided on. The ends of the specimen were attached to the grips by short lengths of $\frac{1}{16}$-in. diameter steel wire passing through the holes shown. The previous experience gained in the Association's laboratories on the problems associated with the machining of lead and lead alloys was placed at the disposal of M.D.1 and a technique developed which enabled small dumb-bell specimens to be produced having a diameter, on the reduced section, accurate to ± 0·0001 in. The rough machining was carried out using steel tools and the final sizing cuts made with a diamond tool. The development of the methods of producing the small specimens on a mass-production basis was successfully carried out by M.D.1. The rods used were of tellurium lead extruded to $\frac{1}{4}$ in. diameter. The rods were extruded in straight lengths, further straightened where necessary between sheets of plate glass, and then heat-treated by holding for three hours at 100 deg. C. and slowly cooling. The precautions which were taken to ensure a uniform product in any one extrusion have already been described.

Each extrusion required separate calibration, and in the early stages this calibration was carried out by the Association on jigs which applied the load through tension springs similar in characteristics to those used in the actual delays. Some few extrusions were also calibrated by dead loading. The springs used applied an initial load of 8 lb., this load falling off slightly as the lead specimen extended, the mean load during a test being less than 8 lb. On the other hand, the dead-loading tests were carried out at a constant load of 8 lb. In consequence of this, shorter timings were given by the dead loading than by the spring-loading tests. This is shown in Fig. 15. It was considered, however, that the dead-loading tests gave the stress-time relationships of the materials and would thus enable springs of other loadings than the standard 8 lb. to be used should the necessity arise. It is of interest to note that under both types of loading a linear relationship is obtained between stress and the logarithm of the life over the limited range covered by the tests. Earlier work by the Association covering a number of lead alloys had shown that,

TABLE II.—EFFECT OF ANNEALING TEMPERATURE OF LEAD SPECIMENS ON TIMING ERRORS.

Diam., In.	Condition.	Average Time, Hours.	Max. Time, Hours.	Min. Time, Hours.	Max.-Av. / Av. Per Cent.	Av.-Min. / Av. Per Cent.	Max.-Min. / Av. Per Cent.
0·0665–0·06675	As extruded	2·078	2·533	1·500	21·9	27·8	49·7
	Annealed at 100 deg. C.	1·94	2·216	1·633	14·2	15·8	30·0
	Annealed at 150 deg. C.	1·32	1·916	0·916	45·2	30·6	75·8
	Annealed at 200 deg. C.	0·566	1·033	0·283	82·5	50·0	132·5
0·0795–0·07975	As extruded	44·5	55·0	41·65	23·6	6·4	30·0
	Annealed at 100 deg. C.	39·0	45·1	34·3	15·6	12·1	27·7
	Annealed at 150 deg. C.	39·5	57·8	30·8	46·4	22·0	68·4
	Annealed at 200 deg. C.	28·5	36·9	17·1	29·5	40·0	69·5
0·085–0·08525	As extruded	82·5	107·5	70·9	30·3	14·1	44·4
	Annealed at 100 deg. C.	69·7	80·5	61·0	15·5	12·5	28·0
	Annealed at 150 deg. C.	77·7	98·0	57·6	26·1	25·8	51·9
	Annealed at 200 deg. C.	55·7	69·8	34·6	20·2	37·9	58·1
0·0951–0·09535	As extruded	268·0	348·5	222·0	30·0	20·8	47·2
	Annealed at 100 deg. C.	217·0	225·5	181·0	16·4	19·9	32·9
	Annealed at 150 deg. C.	271·6	331·0	228·0	21·9	32·2	38·0
	Annealed at 200 deg. C.	225·0	259·0	181·0	15·1	24·3	34·6

for tests under constant load and extending for periods up to four years, a linear relationship was obtained between the logarithm of stress and the logarithm of life.

When 15 separate extrusions had been calibrated the results were analysed to determine how the timings were being affected by variations in grain size within each extrusion. The variations in grain size were judged from the grain sizes measured at the beginning, middle and end of the extrusion. Thus when samples were taken from these positions grain counts were made on five separate fields on each sample and the grain size variation was considered as the difference between the extreme values given by these counts. The extreme variations found in this way are shown in Table I, opposite. Some of these extrusions had been calibrated for short timings, *i.e.*, less than 20 hours, and the rest for long timings of 1 to 14 days. The results were examined in these two separate categories as shown in Fig. 16, opposite.

Variations in timing obtained on the assembled delay are the sum of variations due to: (*a*) the lead itself, particularly its grain size; (*b*) errors in machining and measuring the size of the lead specimen; (*c*) frictional effects in the mechanism; and (*d*) errors in the springs. Thus grain size differences can only be responsible for a part of the total timing variations, but that variable grain size does have a general effect is shown by the two diagrams of Fig. 16, particularly for slow timings.

The specification for the delay required the maximum error to be within the limits $\pm 33\frac{1}{3}$ per cent., *i.e.*, the sum of the greatest errors must not exceed $66\frac{2}{3}$ per cent. Timings obtained under laboratory conditions are likely to show smaller errors than those obtained from mass-produced delays. It was agreed, therefore, that the outer limits of timing errors in calibration should not exceed ± 25 per cent. The diagrams of Fig. 16 showed that to meet this requirement the maximum grain-size variation should not exceed 20 per cent. of the mean grain size. Since such a close tolerance for grain size could not be guaranteed by the lead manufacturer it became necessary to select those extrusions which satisfied the requirements and scrap the others. It was found in practice that this necessitated the scrapping of about 25 per cent. of the extrusions produced. It is important to note that, within reasonable limits, the mean grain size of the lead is not of prime importance, since the calibration takes that into account. What is of the greatest importance is the variation in grain size within any one extrusion.

A series of tests was carried out in co-operation with M.D.1 to test if the annealing treatment given the straightened rods was the most suitable one from the point of view of reproducibility of timing in the assembled delay. For this work one extrusion (BNF mark JTY) which had shown zero grain size variation between the front, middle and end of the extrusion was used. (Where annealing treatments were given they consisted of three hours at the particular temperature followed by slow cooling in the annealing oven.) The rods were supplied to M.D.1 with four different treatments and four different sizes of lead gauge pieces were machined, giving four different nominal timings. Delays incorporating these gauge-pieces were produced in the assembly lines and tested. The results of the tests are given in Table II, opposite, and are also plotted in Fig. 17. All four curves show a minimum error in timing for specimens annealed at 100 deg. C.

A section through the L-delay in its final form is shown in Fig. 18. The lead gauge piece or specimen is free of stress as long as the starting pin is in position, the load applied by the stretched spring being taken by the part *a* of the starting pin. As soon as the starting pin is withdrawn the spring load acts on the lead gauge-piece, which extends with time until fracture occurs. Fracture releases the spring and the striking pin is pulled down, striking the percussion cap and either exploding the detonator at *b* or igniting a slow-burning gunpowder fuse which, in turn, is connected to the detonator. It will be noted that the delay is perfectly silent in action (up to the moment of the striking of the cap) and hence its presence cannot be detected by listening apparatus.

THE INTERNATIONAL RAILWAY CONGRESS, LUCERNE.

(*Continued from page* 66.)

WE continue below our account of the reports and the summary of the reports on reducing the weight of rolling-stock, both of which were prepared for the International Railway Congress Association's fourteenth session, which was held at Lucerne from June 23 to 28, 1947.

CARRIAGE UNDERFRAMES AND BODIES (*continued*).

An important consideration in the use of steels for the construction of carriages is resistance to corrosion. Steels containing a small proportion of copper have been used in Switzerland and Spain; and chrome-nickel steel made by the Budd process, with a tensile strength of over 63 tons per square inch and rustless properties which dispense with the necessity for further protection and also allow thinner sheets to be used for the body, has been employed to a small extent in France and on the North Milan Railway. Other measures adopted to prevent corrosion include efficient arrangements for ventilation and drainage to dispose of water and condensate, and the use of special paints and coatings, some of which also serve as heat and sound insulators. The use of a considerable proportion of light metals or alloys in the construction of carriages has not progressed, generally, much farther than experiments with prototype vehicles. The Swiss Federal Railways, however, ordered 27 lightweight coaches in 1942 and 1943 for the 1-m. gauge Brünig line, which is part rack and part adhesion. Owing to the severe gradients of the line and the shortage of steel which prevailed at the time, it was decided to use aluminium alloys for the underframe, except that the headstocks and the central longitudinal members connecting them to the bogie pivot transoms were fabricated from steel plate. Despite an increase in length of 2-m. compared with previous designs, the use of improved brakes, and the fact that previous designs had incorporated lightweight bodies of aluminium-sheathed wood, the new design, using aluminium alloys for the underframe, resulted in a reduction in weight of 19 per cent.

Usually, however, the use of aluminium or light alloys is restricted to the body. Even in this application, the joining of light metals to steel presents difficulties in manufacture, and requires measures to prevent corrosion. The latter problem is solved in several ways, such as the insertion of wood spacers, the use of protective coatings and cadmium-plated screws for joining.

BOGIES.

Since the weight of the bogies may account for 25 to 38 per cent. of the total tare weight of a coach, the reduction of the weight of bogies is of importance. For economic reasons, the design of lightweight bogies is often compromised by the desirability of achieving some interchangeability with existing standard parts, but in the case of bogies designed without regard to existing types, a reduction in weight of over 35 per cent. has been achieved. In the latter case, also, there are opportunities for evolving new principles of design, as with the Swiss Federal Railways' use of torsion-bar suspension, to which reference will be made later. As a rule, however, the Pennsylvania-type bogie with double suspension, and swing bolsters, is used for lightweight coaches. One half of the springing bears directly on the axleboxes, or indirectly through equalising beams. On the French and Swiss railways a reduction in weight has been achieved by decreasing the distance between axles.

A reduction in weight of the carriage underframe and body naturally affords an opportunity for reducing the strength, and therefore the weight, of the bogies. It is particularly important to endeavour to reduce the unsprung weight, and this has been achieved by using hollow (forged or bored) axles, monobloc wheels with thin webs corrugated radially, or aluminium-alloy wheel centres. Axleboxes are generally of cast iron or cast steel, and apart from straightforward lightening of existing designs, the only improvements noted were the fabrication of axleboxes from steel plate by three British railways, the Ceylon Railways, and some in the United States; and the increasing application of roller-bearings, especially in the United States. In some designs, horn blocks have been dispensed with, and the axleboxes are restrained by a system of links or equalisers. Wear and slackness are thereby reduced. According to Mr. Turbett's report on behalf of English-speaking countries, bogie frames for carriages are generally fabricated, either riveted or welded, the latter being the more recent development. In the special report which he prepared for the session, Mr. José de Aguinaga, summarising rolling-stock practice on the Continent, notes that welded fabricated frames are general. Swing bolsters have been lightened by using more effective sections, and by relieving the load on the centre pivot by means of side bearing surfaces.

The ratio between the unladen and laden weights of a lightweight coach being more significant than the same ratio for a conventional coach, some suspension systems for the former are arranged with supplementary springing, which only comes into play when the deflection of the suspension reaches a predetermined value. The use of coil springs is increasing, and as they have not the same shock-absorbing effect as leaf springs, it is necessary to provide shock absorbers. Rubber is frequently used for eliminating undesirable vibrations. A notable example of the use of torsion-bar suspension, to which reference has already been made, is provided by the Swiss Federal Railways type SIG bogies for lightweight corridor coaches. Compared with the previous design, a reduction in wheelbase from 9 ft. $10\frac{1}{2}$ in. to 8 ft. $10\frac{1}{2}$ in. was effected, and the weight was reduced from 12,477 lb. to 8,002 lb., a reduction of 36 per cent. It was found that when tyre wear on these bogies reached a certain stage, it gave rise to objectionable oscillations, due to the absence of shock-absorbing properties in torsion-bar suspension (similar to coil springs), but this has been overcome by fitting shock absorbers.

No significant uses of special steels for bogies are reported. Most railways use ordinary mild steel, and a few use a semi-hard steel for the rolled sections forming the frame and swing bolster. Axles are usually made from steel of 35 to 40 tons per square inch tensile strength. Mr. José de Aguinaga drew attention to the low-alloy cast steels used by United States railways with the object of improving mechanical welding characteristics. Light alloys have been applied but little to the construction of bogies, owing to their comparatively low elastic limits and the violent shocks to which a bogie is subjected. The Swiss Federal Railways' experiment, already noted, of using aluminium-alloy wheel-centres, however, does afford some prospect of the extended application of light alloys to bogies. Axleboxes of aluminium, with wearing surfaces of steel, are reported. An interesting development is reported by the Michelin Company, in the construction of six carriages with pneumatic tyres. The tare weight of each is expected to be about 16 tons.

BUFFING GEAR, DRAW-GEAR, AND BRAKES.

As it is usually necessary for a lightweight coach to be suitable for coupling to older coaches, it is not always easy to make major alterations to the design of the buffing- and draw-gear. Centre automatic couplers with through drawbars, which are eminently suited to the central-girder type underframe, are used in the United States; but in most European lightweight designs the headstocks sustain the tractive forces, although, in some cases, there is a direct connection to the bogie-pivot transom. In general, springs are being replaced by rubber for draw-gears —a change which results in a reduction in weight. The two-buffer arrangement which is common in Europe can be lightened more effectively if the buffers are independent; but most lightweight carriages are provided with equalising beams to the twin buffers, especially for main-line service. Leaf springs have been abandoned and the equalising system made as light as possible, thereby reducing the total weight of the equipment by about 50 per cent. Special steels for draw-gear are common in the United States, and are gaining favour in Europe,

but only slightly in the United Kingdom. Light metals are not used for draw-gear, but have been employed for parts of the buffing-gear, as also have special steels.

As the coefficient of friction for brake blocks on wheels decreases with increasing speed, and as light-weight coaches are often used on high-speed services, it has been found necessary to provide brake equipment which automatically exerts a braking force which is a function of the speed. At high speeds, the ratio of braking force to wheel load may be more than unity. The weight of this additional equipment has tended to nullify the reduction in weight of brake-gear achieved by careful design and the use of special steels and light alloys, although, apart from this consideration, the weight of brake-gear has been reduced by over 40 per cent. Cast iron has been replaced by steel pressings and fabricated steel plates for brake cylinders and reservoirs, and, in a few cases, light alloys have been used. The brake rigging is reported to be always made of alloy steel in the United States, but rarely in Europe. The Belgian National Railways, however, have been trying the use of light alloys for rigging. Brake pipes are now being made of cold-drawn steel and light alloys.

Carriage Fittings and Accessories.

In so far as the design of coach interiors, to provide increased comfort and convenience for passengers, is as important to the railways as the reduction of the total weight of the rolling-stock, it is virtually impossible, if indeed the effort is worthwhile, to find a basis on which to compare new designs with old. It is only possible to note, in a general way, that while every effort is made to eliminate unnecessary weight of fittings, the standards of furnishings and comfort are at least maintained, and usually improved. In the United States, for example, and in other countries where the conditions of travel are such as to warrant the increased cost, air-conditioning equipment is common in modern rolling stock. The space allowed for each passenger, or the distance between compartment walls, has been increased in many cases.

The weight of lighting equipment has been reduced by improved electrical and mechanical designs. In particular, the efficiency of generators has been increased, and this has permitted a reduction in the weight of accumulators of 50 per cent. in some cases. The application of fluorescent lighting is being extended. The weight of steam-heating and electric-heating equipment has been reduced by the use of light alloys for the former and more efficient lay-outs for the latter. The French National Railways have experimented with a system of heating in which air, heated by steam or electricity, is discharged from under the seats. In the United States, air-conditioning equipment has been improved, and, in some cases, the heating system is incorporated with it. Double-glazing is usually associated with air-conditioning, although it represents additional weight.

Numerous materials, both conventional and proprietary, are used for the interior surfaces of carriages. Aluminium, aluminium-faced plywood, and compressed-wood products, are some of the materials used. Floors usually incorporate heat- and sound-insulating materials, and, as already mentioned in connection with the design of carriage bodies, they are sometimes designed to provide part of the strength of the carriage as a whole. Light-alloy pressings and wooden frames covered with sheet aluminium are being used for doors, and the Swiss Federal Railways, in particular, have replaced the conventional type of door by a neat and convenient folding and sliding type. The French National Railways have designed inter-compartment walls with frames of steel tubes welded together. Water tanks are usually of copper or zinc, but on the Brünig line of the Swiss Federal Railways, which, as previously mentioned, is a part rack and part adhesion line, aluminium has been used for the tanks. Metal tubes are being employed to an increasing extent for the frames of seats and luggage racks, and in the United States individual rotating and reclining seats are finding favour. Miscellaneous fittings are being made of light alloys and plastics.

(To be continued.)

THE ROYAL AGRICULTURAL SHOW AT LINCOLN.

(Concluded from page 79.)

In the early days of mechanised transport, the farmer had to rely mainly on vehicles designed solely for use on roads, and, as a consequence, he tended to retain the horse-drawn wagon. This state of affairs, however, no longer exists and several types of vehicle are now available, either adapted from existing commercial vehicles or designed specially for the farmer. Messrs. Commer Cars Limited, Luton, were showing one of their 4-5 ton Superpoise chassis fitted with a detachable double-deck body, manufactured by Messrs. Carmichael and Sons (Worcester), Limited, which can be removed as a unit from the vehicle. It is illustrated in Fig. 23, opposite, and it will be noted that the top of the body is carried forward over the driver's cab, thus increasing considerably the carrying capacity. The body is carried on a strong platform and it is held thereto by six quick-release bolts. The main structure of the body is of composite wood and steel construction and the fitting of an extra deck results in an exceptionally rigid structure. Usually cattle are carried on the lower deck and either calves or sheep on the upper deck. Movable partitions are fitted to the upper deck and these are designed so that the two rear sections act as loading ramps. The chassis is fitted with a six-cylinder side-valve petrol engine having a bore and stroke of 3·35 in. and 4·72 in., respectively, and developing 80 brake horse-power. The drive from the engine is transmitted through a single dry-plate clutch to a four-speed gearbox fitted with helical constant-mesh gears for third and top speeds. The rear axle is of the fully-floating pattern with spiral-bevel final drive, the pinion being "straddle" mounted. The single front wheels and twin rear wheels are fitted with 34-in. by 7-in. pneumatic tyres, and hydraulic brakes operate on all four wheels.

An example of a mechanically propelled vehicle designed in the first instance for use by farmers was exhibited on the stand of Messrs. S. E. Opperman, Limited, Boreham Wood, Hertfordshire. This vehicle, known as the Motocart, is illustrated in Fig. 24, opposite, and it will be seen that it has three wheels with the single-wheel located at the front, an arrangement which results in exceptional manœuvrability. An interesting feature of this machine is the fact that it is driven through the single large-diameter front wheel, the power unit forming a single unit with the wheel. By adopting this layout, it has proved possible to fit a large-diameter driving wheel, which is essential for cross-country work, and yet retain a comparatively low load-carrying platform. The power unit is a single-cylinder air-cooled four-cycle petrol engine having a bore and stroke of 85·7 mm. and 102 mm., respectively, and developing 8 brake horse-power. It is fitted with an impulse-starter type of magneto, and the throttle is arranged to operate through a centrifugal governor. The drive from the engine is taken to a single dry-plate clutch through a roller chain, the chain case being clearly visible in Fig. 24. The clutch drives a four-speed gearbox located immediately behind the engine and the output shaft from the gearbox is fitted with a pinion which meshes with a gearwheel bolted to the hub of the front wheel. The layout of the steering gear will be apparent from a study of the illustration, the steering wheel being located at right angles to the front-wheel column and arranged to turn the combined engine, transmission and front wheel by a steering box fitted above the front-wheel column pivot. The chassis is of exceptionally robust construction, the two side members being fabricated from ¼ in. thick steel plate to form 14 in. by 2 in. channel sections, while the swan-neck is reinforced with steel plates having a thickness of ½ in. The front wheel is fitted with a 9-in. by 24-in. tractor-type tyre, and it will be noted that the wheel can be removed and replaced with comparative ease, owing to the absence of forks. The rear wheels are fitted with 32 in. by 6 in. truck-type tyres and are equipped with Girling internal-expanding brakes. The vehicle has a good cross-country performance, the overall gear ratios through the transmission being 137·5 to 1 in first gear, 79·5 to 1 in second, 43·5 to 1 in third, and 21 to 1 in top gear, while the reverse ratio is 165 to 1. The corresponding maximum road speeds are 2 m.p.h., 4 m.p.h., 6·8 m.p.h. and 11·2 m.p.h. in first, second, third and top gears, respectively; the speed in reverse gear is 1·6 m.p.h. The maximum load that can be carried is 30 cwt. and the overall dimensions are: length, 13 ft. 11 in., width, 6 ft. 7 in., and height, 6 ft. 11 in.

For obvious reasons, the most popular means of transportation on the average farm is either the two- or four-wheeled trailer. An interesting type of two-wheeled trailer, the Lolode, was shown on the stand of Messrs. Low Loading Trailer Company Limited, Bedford, which although capable of carrying a load of 15 cwt., can be towed behind a medium-size private car. The trailer is illustrated in Fig. 21, opposite, and it will be noticed that the ground clearance is exceptionally small. This has been brought about by fitting independently sprung wheels, an arrangement which allows the axle to be dispensed with, thereby effecting a considerable reduction in weight in addition to reducing the tendency to roll when carrying top-heavy loads. The trailer may be regarded as having no chassis, as the sides of the body form the longitudinal members; these, together with the front panel, are fabricated from 16-gauge mild-steel plate welded to light angle-section members, the sides being stiffened further by the outrigger braces visible in the illustration. The tailboard is of composite wood and steel construction and folds down to form a ramp. A wooden floor is fitted and this is supported by four cross members, the main cross member being a steel tube, 3 in. in diameter, which also serves as a pivot for the suspension assemblies. The suspension is by quarter-elliptic springs which are fitted to crank arms pivoting about the steel tube referred to above, the front ends of the springs being shackled to the trailer body, as shown in the illustration. Internal expanding brakes are fitted to the roadwheels, the brake drums having a diameter of 12 in.; the brakes are operated on the overrun principle and a hand parking brake is inter-connected with the operating linkage. When required for use with a private car, it is fitted with a tow bar having a height of 1 ft. 2½ in. from the ground, but when used with a commercial vehicle a higher tow bar is used having a height above the ground of 1 ft. 10½ in. Apart from the floor and tailboard, the complete trailer is made from steel and is particularly suitable therefore for use in the tropics. Different types of detachable tops are available with the trailer, and these include superstructures and tilts for the transport of cattle and horses.

Messrs. Taskers of Andover (1932) Limited, Andover, Hampshire, also were showing a range of trailers which included a four-wheeled trailer developed originally for receiving grain from the combine harvester. This trailer is illustrated in Fig. 22, opposite, and it will be noted that the body is divided into two sections, both of which can be tipped separately. Although the illustration shows the after section tipped towards the nearside and the forward section tipped towards the offside, it is possible by the removal of the appropriate hinge pins either to reverse this arrangement or tip both sections on the same side; it is also possible to tip only one section alone. The sides and ends of both sections can be removed when required and the trailer body converted into a flat platform, the gap between the two sections being filled in by a bridge piece. The two sections are tipped hydraulically, a separate ram being fitted to each section; the hydraulic pressure is provided by a combined hand pump and reservoir fitted to the front-end of the chassis. The body is of all-metal construction, the flooring, sides and ends consisting of 14-gauge sheet metal reinforced by light angle-section and channel-section members. The sides are hinged from the top and are secured by cam-type fasteners. The chassis frame is constructed from 4 in. by 2 in. channel sections, which are used both for the longitudinals and cross members. The chassis is mounted on half-elliptic leaf springs and the wheels are fitted with 7·20-in. by 15-in. pneumatic tyres.

EXHIBITS AT THE ROYAL AGRICULTURAL SHOW, LINCOLN.

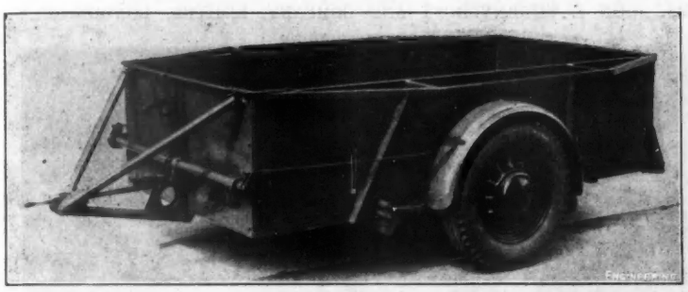


FIG. 21. "LOLODE" 15-CWT. TRAILER MESSRS. LOW LOADING TRAILER COMPANY LIMITED.

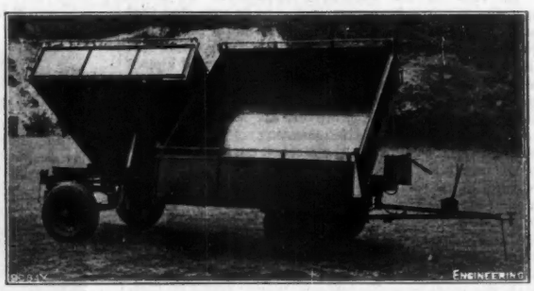


FIG. 22. FOUR-WHEELED TIPPING TRAILER; MESSRS. TASKERS OF ANDOVER (1932) LIMITED.

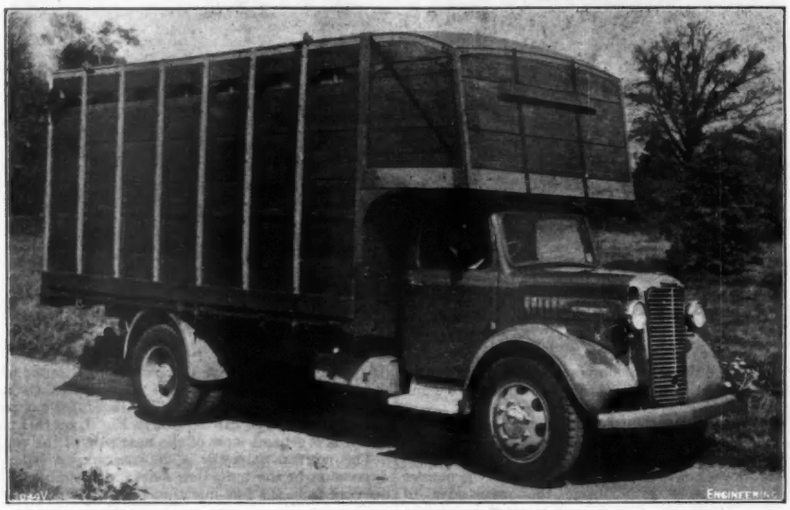


FIG. 23. CARMICHAEL BODY ON "SUPERPOISE" CHASSIS; MESSRS. COMMER CARS LIMITED.

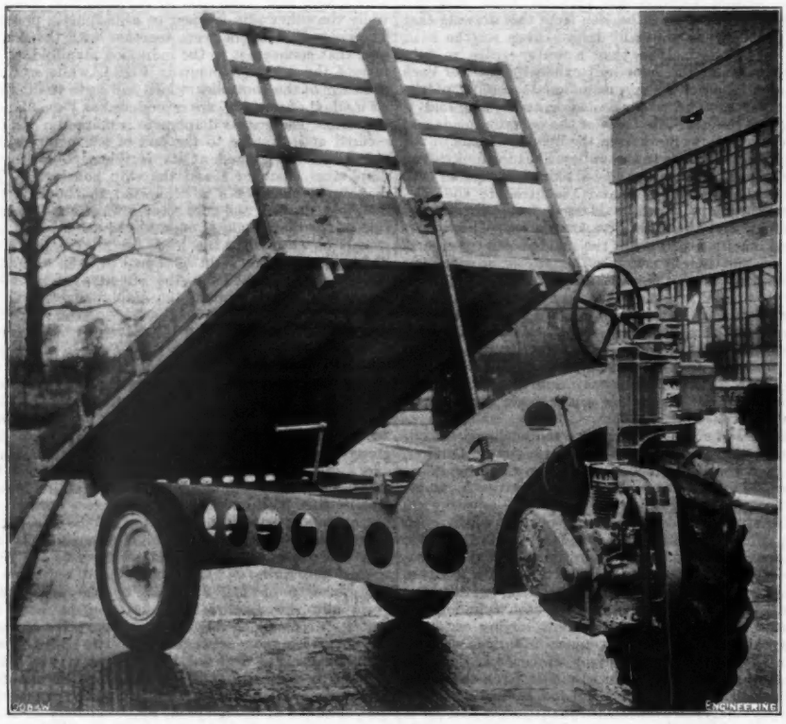


FIG. 24. "MOTOCART" THREE-WHEELED TRUCK; MESSRS. S. E. OPPERMAN, LIMITED.

The provision of his own electrical power is nothing new to the farmer, as even by 1939, only some 63 per cent. of rural dwellers in England and Wales received their electricity supply from the mains. As a consequence, a large number of farms still have to produce their own electrical power, and many exhibits at the Show were concerned with this matter. Among these was a new automatic lighting set which was shown on the stand of the Associated British Oil Engines, Limited. This set, which is of the floating-battery type, is produced in three sizes, namely, 1½ kW at 32 volts, 2 kW at 110 volts, and 4 kW at 110 volts, the set exhibited being the 1½-kW size. The set consists of a 3-h.p. Petter air-cooled petrol engine, belt-driven generator and automatic switchboard, mounted on a fabricated-steel baseplate. The dynamo is a drip-proof, fan ventilated, continuously rated, shunt wound machine, and is provided with series turns for motor starting. It is driven by an endless V-belt and is controlled by specially-designed switchgear which works in conjunction with a battery having sufficient capacity to deal with normal lighting loads. In operation, the system provides that loads up to a pre-determined value are supplied by the battery, the generating set being inoperative. When the load exceeds this predetermined value, the set is started automatically by "motoring" the dynamo. A safety device is provided to ensure that, in the event of the engine failing to start through lack of petrol or some other cause, the "motoring" current is cut off, thereby preventing damage to the battery. When the set is running, the speed of the engine is controlled by a magnetic governor, which is associated with the load current, and the generator current not required to supply the load is used for charging the battery. This combination ensures that the engine operates only when an economic load is available, loads below this value being supplied from the battery. The current value at which the set starts and the load is taken over by the generator is approximately 20 per cent. of the rated load, but provision is made for alternative settings.

Obviously, there were many exhibits at the Show that we have been unable to mention, owing to lack of space. The machines described have been selected because they illustrate the advances made since the last Royal Show. Probably, this year's Show was the most successful ever held, all attendance records having been broken, and it is hoped that this indicates a growing interest in agriculture.

CANADIAN PRODUCTION OF PAPER.—The output of newsprint paper in Canada totalled 369,490 tons in April, 1947, against 337,862 tons in April, 1946.

NICKEL IN THE R.M.S. "QUEEN ELIZABETH."—A publication issued by the Mond Nickel Company, Limited, Grosvenor House, Park-lane, London, W.1, illustrates the numerous applications of nickel and nickel-containing alloys in marine engineering. The pamphlet is entitled "Nickel in the R.M.S. 'Queen Elizabeth'" and the applications described and illustrated cover the propulsion machinery, pumps, electrical equipment, navigational and safety equipment, catering appliances, sanitary fittings and interior decoration.

PETROL-INJECTION ENGINE FOR COMMERCIAL VEHICLES.

PETROL-INJECTION ENGINE.

MESSRS. JOHN I. THORNYCROFT AND COMPANY, LIMITED, LONDON.

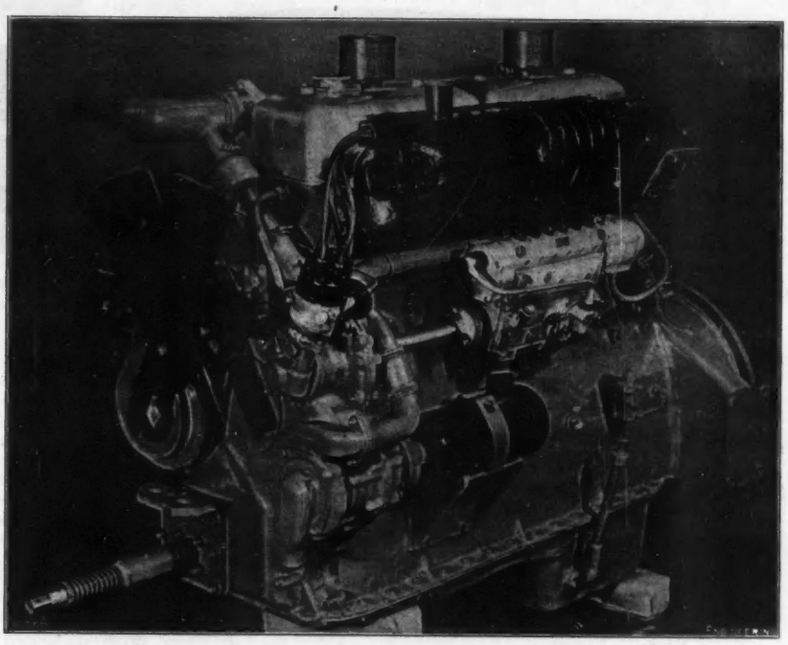


FIG. 1.

IN view of the successful application of petrol injection to aircraft engines, it was to be expected that attempts would be made to develop similar equipment for use on automobile engines. The single-point fuel injector, as used on aircraft engines, is now well known and its use is becoming increasingly popular. The problems to be overcome in applying similar equipment to automobile engines, however, are somewhat more complex, due to the variable operating conditions and to the fact that, whereas on the aircraft engine the single-point fuel injector replaced a carburettor which had become more complicated as aircraft engine development progressed, the same cannot be said in relation to those carburettors fitted to standard automobile engines. These are comparatively simple appliances, easy to maintain, with few moving parts to wear, and before operators would consider replacing them with the more complicated and more expensive fuel-injection system, either a definite saving in fuel consumption or a considerable increase in output would have to be shown.

Nevertheless, Messrs. John I. Thornycroft and Company, Limited, Basingstoke, Hampshire, considered that there was scope for improvement in the present carburettor-type engine, particularly as used in heavy commercial vehicles, and decided to investigate the possibilities of petrol injection. The principal claims made for petrol injection are: better volumetric efficiency, brought about by the use of large-bore induction pipes and the absence of the carburettor choke, a hot-spot is not required, better distribution and atomisation of the fuel, better control of the mixture within the throttle range, and the use of cold air drawn in from outside the bonnet.

The first experiments were confined to a single-cylinder engine and the results showed that a considerable gain in output with reduced fuel consumption could be obtained. In view of the success of these early experiments, it was decided that the investigation should be carried a stage farther and the effects of converting a six-cylinder engine ascertained. One of the firm's standard N.R. 6 compression-ignition oil engines was selected and it was found that, with petrol injection, one third extra torque could be obtained, and the output could be increased by some 50 per cent. These results were considered good enough to warrant putting a similar engine into production, and Messrs. Thornycroft claim to be the first firm in this country to produce a petrol-injection engine for commercial use. It should perhaps be mentioned that the fuel-injection unit replaces the carburettor and is not to be confused with direct injection as applied to compression-ignition oil engines.

It was decided to base the production petrol-injection engine on the existing N.R.6 oil engine, as apart from the success obtained during early trials and its general adaptability, this engine is sufficiently robust to withstand the increased loads brought about by the use of petrol injection. Furthermore, as the N.R.6 oil engine was already in production, the initial outlay was reduced considerably and, at the same time, the provision of spare parts was simplified. The N.R.6 petrol-injection engine is illustrated in Fig. 1, on this page, and in its general form is similar to the N.R.6 oil engine, the main difference between them being the provision, on the new engine, of re-designed cylinder heads, a special water-cooled exhaust manifold, new pistons, a new induction system and a drive to the distributor of the ignition circuit.

The N.R.6 petrol-injection engine has six cylinders, with a bore and stroke of 4¼ in. and 6 in., respectively, giving a capacity of 7,880 cub. cm. It is of monobloc construction, the cylinders and crankcase forming a single casting. The cylinder bores are fitted with dry cast-iron liners of the flangeless type. The crankshaft is made from Nitralloy steel, the journals and crankpins having diameters of 3½ in. and 3 in., respectively; it is of solid construction and is drilled for bottom-end lubrication. It is carried in seven bearings of the steel-backed, white-metal-lined type, which are located by dowels fitted to the crankcase and bearing caps. Solid-skirt aluminium-alloy pistons are fitted, and each piston has three pressure rings and one slotted scraper ring; provision is made for fitting an additional scraper ring should oil consumption increase later in the life of the engine. The H-section connecting rods are made from 1 per cent. chromium steel and are fitted with steel-backed bottom-end bearings, the upper halves of which are lined with lead-bronze and the lower halves with white metal; the top-end bearings are phosphor-bronze bushes, the floating gudgeon pins being retained in position by internal Circlips. The cylinder head is cast in two separate parts, each of which covers three bores, and they are fitted with overhead valves operated in the usual manner by rocking levers and push rods. The main bearings, bottom ends, camshaft bearings and overhead-valve gear are supplied with oil under pressure from a rotary-gear pump which delivers the oil through a combined oil filter and cooler. Cooling is effected by a centrifugal pump and engine-driven fan.

As previously mentioned, the cylinder heads are of a new pattern, and are designed to accommodate the injectors as well as the sparking plugs. The injectors are "let-down" into the inlet ports so that the nozzles are approximately ¼ in. from the undersides of the valve heads, the top of each injector being just outside the valve-spring diameter. This arrangement is illustrated in Fig. 2, opposite, which shows a transverse section through the cylinder head and one of the pistons. It will be seen from this drawing that the inlet port is unusually large; even so, the head has been designed so that a water space is provided between the inlet and exhaust ports for each cylinder in order to ensure adequate cooling of the valve seats. The water-cooled exhaust manifold is bolted to the near-side faces of the cylinder heads and the cooling water flows from the cylinder heads to the manifold and thence to the radiator header tank. The main object of the water-cooled exhaust manifold is to reduce the amount of heat transmitted to the fuel-injection pump, which is located just beneath the manifold, and thus avoid vapour locks. The water-cooled manifold also keeps the under-bonnet temperature low and thereby assists in the prevention of vapour locks in the service pipes leading to the fuel-injection pump. Special attention has been paid to crankcase breathing; air is taken in through two Vokes air filters situated on top of the valve covers and then passes through the valve gear chamber, the tappet gear, and the sump to a large-diameter breather pipe fitted with an Amal flame trap, and thence into the induction manifold on the atmospheric side of the throttle.

The fuel injection equipment was developed in conjunction with Messrs. C.A.V., Limited, Acton, London, W.3, and consists of an injection pump and injectors, automatic mixture control, excess-fuel device for starting, feed pump and the usual filter. The injectors are of the spring-loaded, poppet-valve type which open at approximately 367 lb. per square inch. Basically, the injection pump is a standard unit as used on commercial-vehicle oil engines and it is fitted with plungers having a diameter of 7⅛ mm. and a stroke of 10 mm., there being a separate plunger for each cylinder. It is fitted with a modified camshaft having eccentric cams which provide a longer injection period, while in order to give greater accuracy of control, the spill helices of the plungers have a smaller pitch than that used for oil engines, the control rod having a proportionately longer travel. The pump is secured to a bracket bolted to the nearside of the engine and it is driven directly by the timing chain. The fuel-pump drive also serves to drive the ignition distributor which is of C.A.V. manufacture and incorporates an automatic advance mechanism. The fuel-injection pump and the distributor can be seen in Fig. 1, on this page, which is a general view of the near side of the engine.

The mixture strength is determined by using the depression in the induction manifold to influence the delivery from the fuel-injection pump. This is accomplished by the mixture controller which consists of a leather diaphragm fitted to the rear end of the control rod, one side of the diaphragm being sealed from the atmosphere and connected to the induction manifold while the other side is open to atmospheric pressure. The controller can be seen, together with the flexible pipe that connects it to the induction manifold, at the rear of the injection pump in Fig. 1, while sectional drawings of the controller, which will serve to illustrate its method of working, are reproduced as Figs. 3 and 4, opposite. The leather diaphragm is marked *a* and it is secured at its centre to the end of the pump-control rod *b*; it is clamped at its periphery between the diaphragm chamber *c* and the stop housing *d*. The diaphragm chamber *c* is connected to the induction manifold through the connector *e* while the left-hand side of the diaphragm is open to the atmosphere, and it will be clear that the force tending to move the diaphragm to the right is equal to the induction depression multiplied by the effective area of the diaphragm. Movement of the diaphragm, and therefore, of the control rod, to the left increases the fuel supply to the injectors and the travel in this direction is limited by the diaphragm stop *f* which is integral with the housing *d*. Conversely, movement to the right decreases the fuel supplied to the injectors, but movement in this direction is opposed by the three springs *g*, *h*, and *i* housed inside the chamber *c* and arranged to make contact with the diaphragm progressively during its travel to the right. In Figs. 3 and 4, the diaphragm is shown in the position for full load when the manifold depression is at its lowest, and in this position only the outermost spring *g* is in contact with the diaphragm. As the throttle is closed, the subsequent reduction in pressure in the manifold causes the diaphragm to move to the right against the spring *g* with a consequent reduction in the quantity of fuel delivered by the pump until eventually the diaphragm makes contact with the centre, or cruising, spring *h*. From this point onwards the pneumatic force acts against the two springs *g* and *h* thus causing a decrease in the rate at which fuel delivery is reduced for a given change in manifold depression. When the manifold depression approaches that obtained at idling speed, approximately 18 in. of mercury, the diaphragm makes contact with the innermost spring *i*, known as the idling spring, thereby

PETROL-INJECTION ENGINE FOR COMMERCIAL VEHICLES.

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Fig.2.

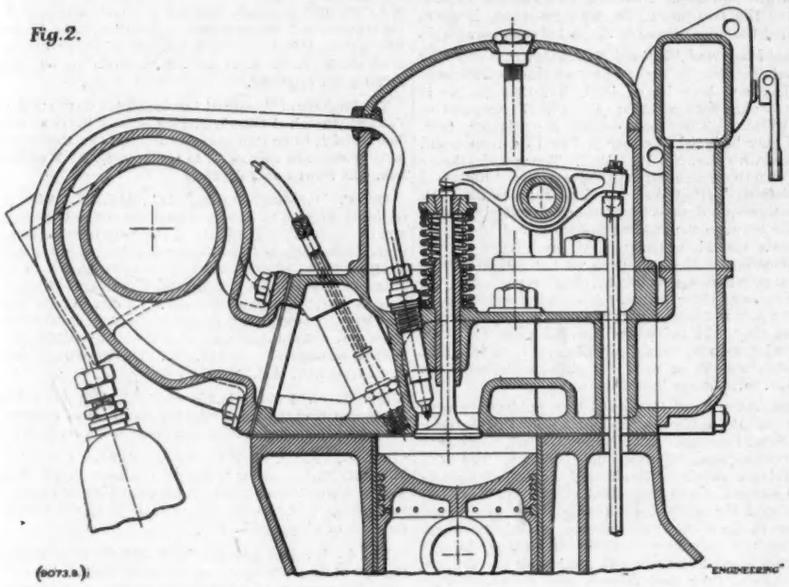


Fig.5.

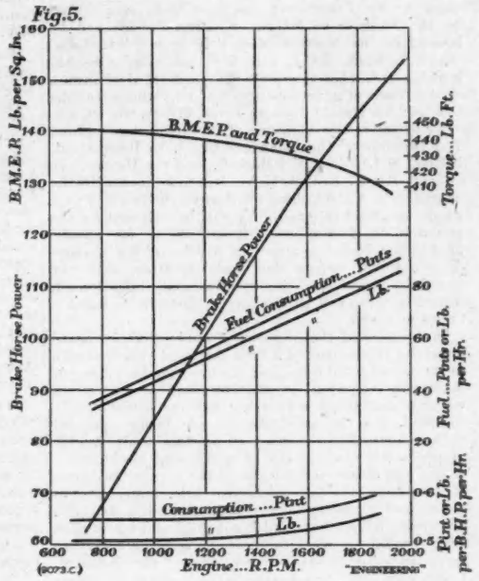


Fig.3.

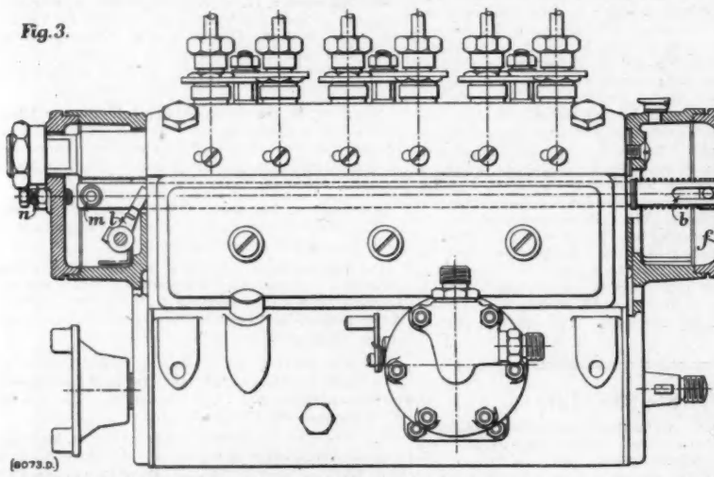
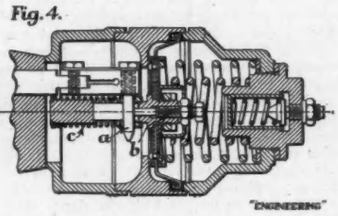


Fig.4.



giving a further stiffening of the spring rate and limiting the travel of the diaphragm to the right. The position of the idling spring and therefore, the idling speed, can be adjusted by the screw *j* and the locknut *k*, while the positions of the springs *g* and *h* can be adjusted by the insertion of shims.

The diaphragm is connected to the control rod in such a manner that the maximum-fuel setting of the pump can be altered and the mixture controller overridden in order to obtain excess fuel for starting purposes. The method by which this is done is illustrated in Fig. 4, which is a sectional-plan of the controller. It will be seen that the axes of the control rod and the diaphragm are offset, the control rod being located behind the diaphragm centre piece. They are connected through the pin *a*, which is fixed to the end of the control rod and enters a slot formed within the diaphragm centre piece. The position of the pin within the slot is determined by the screw and locknut *b*, the pin being held against the screw by the action of the spring *c*. It will be realised that if the screw *b* is screwed into the diaphragm centre piece, the control rod will be moved to the left, thus increasing the maximum delivery of the pump. Conversely, rotation of the screw in the opposite direction will lessen the maximum delivery. Excess fuel for cold starting is provided by moving the control rod manually to the left against the spring *c*, thus increasing the delivery of the pump above that required for full load. The control rod is moved by the lever *l* (Fig. 3), which is housed in a small casting fitted to the forward end of the pump and is actuated by a control situated in the driver's cab. When the lever *l* is moved, it makes contact with the roller assembly *m* fitted to the control rod and moves it to the left, the excess motion of the control rod over the diaphragm being absorbed by the spring *c*, as mentioned previously. The travel of the control rod to the left, however, is limited by the adjustable stop *n*.

The engine has a compression ratio of 6·92 to 1, which gives a compression pressure of 175 lb. per square inch and an explosion pressure of 650 lb. per sugare inch at 1,400 r.p.m. An idea of the performance of the engine can be gained from the curves reproduced in Fig. 5, from which it will be seen that the maximum torque is in the neighbourhood of 445 lb.-ft., which is equivalent to 140 lb. per square inch brake mean effective pressure at 800 r.p.m., while the brake horse-power is 150 at 1,900 r.p.m. Fuel-consumption curves also are shown in Fig. 5, reference to which shows that a full-load consumption of 0·508 lb. per brake horse-power hour is obtained at 800 r.p.m., while at 1,800 r.p.m., the consumption rises to 0·55 lb. per brake horse-power hour. The engine was fitted to a vehicle, the gross laden weight of which equalled 22 tons, and the consumption figures obtained from extensive road trials averaged 6·2 miles per gallon, while the average speed was 25·9 m.p.h. It is interesting to note the corresponding figures for the 100-brake horse-power N.R.6 oil engine, which has a compression ratio of 16 to 1, a compression pressure of 562 lb. per square inch, and an explosion pressure of 963 lb. per square inch at 1,400 r.p.m. This engine develops 100 brake horse-power at 1,800 r.p.m. and, under similar conditions, the fuel consumption was equivalent to 8·25 miles per gallon. The average speed, however, was only 16 m.p.h., and it will be clear from this comparison that the petrol-injection engine should prove advantageous in circumstances which require high average speeds and quick acceleration, such as are desirable for the operation of public-service vehicles.

CATALOGUES.

Overhead-Line Materials.—Messrs. W. T. Henley's Telegraph Works Company, Limited, 51, Hatton-garden, London, E.C.1, have issued a catalogue of the material manufactured by them for constructing overhead transmission lines. Details of service accessories, outdoor terminal boxes, crossovers for high-voltage lines, isolating switches and insulators are among the many items listed. Useful information is also given regarding the data required to estimate the cost of erecting a line, as well as of the current rating for the copper conductors available for this purpose.

Stone Breakers and Ore Crushers.—Messrs. Hadfields, Limited, East Hecla Works, Sheffield, have sent us a fully-detailed booklet (No. 470) of their jaw breakers for stone and ore. The machines dealt with are four sizes of sectional frame breakers for reducing large pieces of material to either 5 in. or 7 in. in diameter; the maximum output of the largest machine being 310 tons per hour of hard limestone to 7 in. pieces. In addition, there are particulars of 11 sizes of solid steel frame machines with outputs ranging from 3 tons to 140 tons of crushed stone per hour.

Switchgear.—A catalogue dealing with metalclad switches, switch fuse and distribution gear has been issued by Cantie Switches, Limited, Northgate Works, Chester. The standard range is up to 500 amperes at 660 volts for switches, switch fuses and change-over switches, and up to 100 amperes at 660 volts for fuse boards. The switch mechanisms are of the well-known Cantie bolt-lock type and the fuses, which are re-wirable, are fitted with unbreakable bridges. High rupturing capacity fuses, with a rupturing capacity of 25 MVA, can be provided as an alternative.

NATIONAL COLLEGE OF HOROLOGY.

SOME years ago it was decided to found a National College of Horology and Instrument Technology, and a scheme establishing the College, and making regulations for its government, has now been promulgated by the Minister of Education. The College will be housed in the Northampton Polytechnic, St. John-street, London, E.C.1, and Sir Allan Gordon-Smith, K.B.E., D.L., has accepted the position of chairman of the board of governors appointed to administer the College; Sir Harold Spencer Jones, F.R.S., the Astronomer Royal, is vice-chairman of the board of governors. The Director of the College is Dr. J. E. Richardson, B.Eng., M.I.E.E., A.M.I.Mech.E., and the Head of the College, Mr. R. A. Fell, M.A. In accordance with the intention that the College shall serve the country as a whole, financial responsibility will be assumed by the Ministry of Education, although in so far as the programme includes activities which, in the absence of a national college the local education authority would be expected to provide, financial obligations in regard to these will be discharged through the London County Council.

It is intended that courses of study shall be based upon the attainment of a high degree of practical skill in the use of hand tools and the most modern types of machinery required for the complete production of watches and clocks and other fine mechanisms. To this end, the College workshops are being equipped with a comprehensive range of machine tools capable of producing every detail of watch and clock movements and other instruments to the maximum degree of accuracy. On the theoretical side, instruction in the science necessary for the acquisition of a thorough knowledge of horology and horological and instrument design will be carried to the high level necessary to serve all educational requirements of the industry. In drawing up their programme the board of governors have had particularly in mind the urgent need to train men who will be able, in due course, to fill the higher executive posts. They recognise that the successful establishment of a watchmaking industry, employing the most modern methods of high-grade mass production, can only be achieved by a combination of excellence in craftsmanship, design and organisation.

While the training of craftsmen can be effected locally by co-operation between a factory and a neighbouring technical college, the industry will look to the National College as the source from which will emerge the potential managers, designers and other executive officers, as well as men competent to undertake research with a view to the advancement of manufacturing practice. It is anticipated that the industry will recruit for such key positions by a variety of different avenues, and in accordance with this view two distinct courses of training are offered—the one an advanced full-time course occupying two years; the other a course of one year's duration for graduates in science or engineering. Approach to the former may be through either a general course in horology occupying three years' full-time and entered upon at the age of 16-17, or through a National-Certificate course in engineering or in instrument technology, followed by a modification of the final year of the above-mentioned general course. The alternative post-graduate one-year course is designed for graduates in engineering, physics or some other appropriate branch of science, who contemplate a career in the horological or instrument industries, following upon a period of initiation into the specialised technology and practice. Training in watch- and clock-repair work is regarded as outside the province of the National College, and will continue to be undertaken by the Northampton Polytechnic.

A diploma will be awarded to students successfully completing one of the major full-time courses. According to the course to which they relate, these will be known, respectively, as the College Diploma in Horology; the College Higher Diploma in Horology; and the College Post-Graduate Diploma in Horology. The fee for full-time courses will be 60*l.* per annum. Special arrangements in respect of fees will apply, however, in the case of apprentices in receipt of full wages from employing firms during the period of attendance. The Board of Governors will award six scholarships per annum from funds placed at their disposal for the purpose. These will provide free tuition, together with a maintenance allowance dependent upon the financial circumstances of the candidate. It is proposed, as soon as practicable, to secure hostel accommodation for the use of students who come from outside the London area. In the meantime, suitable lodgings will be found on request by the authorities of the College. The dates of terms for the opening session, 1947-1948, are as follows: Autumn term, Monday, October 6 to Friday, December 19, 1947; Spring term, Monday, December 29, to Wednesday, March 24, 1948; and Summer term, Monday, April 5, to Friday, July 23, 1948.

BRITISH STANDARD SPECIFICATIONS.

THE following specifications of engineering interest have been issued by the British Standards Institution. Copies are obtainable from the Publications Department of the Institution, 28, Victoria-street, London, S.W.1, at the price quoted at the end of each paragraph.

Fused-Plugs and Shuttered Socket-Outlets.—The long awaited specification for the new all-purpose domestic plug has now been issued (B.S. No. 1363-1947). It covers a plug with a rating of 3 kW (13 amperes at 230 volts). This incorporates a cartridge fuse, which may be rated at either 3, 7 or 13 amperes, and complies with B.S. No. 1362-1947. The specification is based on a recommendation in the report on "Electrical Installations" (Post-War Building Studies No. 11), that a three-pin domestic socket-outlet and plug intermediate between the existing 5-ampere and 15-ampere standards should be introduced, and on a second recommendation that all such socket-outlets should be connected in a ring main, thus necessitating the use of fuses at these points. An interesting feature is that the pins in the new plug are rectangular in section so that they will be easily distinguishable from the standard non-fused round-pin plugs. It is intended that they should be used for all new installations. [Price 2*s.* 6*d.*, postage included.]

Copper-Alloy Sand Castings.—The publication of a "Code of Procedure in Inspection of Copper-Base Alloy Sand Castings," B.S. No. 1367-1947, represents an interesting and important development. The need for guidance in the difficult and somewhat controversial subject of the inspection of castings has been appreciated for some considerable time. It is the purpose of the Code "to indicate procedures which will give the maximum possible information on the properties of sand castings with reasonable expenditure of materials, time and labour, and to standardise inspection procedure in order to facilitate industrial inspection and ultimately to assist both the designer and the founder in improving the quality of castings." Castings are classified according to the service they have to perform, and methods of inspection are recommended for each class. The methods advocated for the inspection of material cover chemical analyses and mechanical tests. Tables are given relating the number of chemical analyses to the number of foundry casts, and the number of mechanical tests to the weight of castings. Inspection methods are outlined, together with the procedures recommended for destructive and non-destructive tests. The Code recommends that the wedge test bar be adopted as the tentative standard for copper-base alloy castings. As, however, it is felt that some difficulty may be experienced in meeting the specification requirements for certain materials using this form of test bar, an alternative test bar, cast to shape, is recommended. [Price 2*s.* 6*d.*, postage included.]

BOOKS RECEIVED.

Meter Engineering. A Practical Book on the Installation, Testing and Maintenance of Electricity Meters. By J. L. FERNS. Fourth edition. Sir Isaac Pitman and Sons, Limited, Parker-street, Kingsway, London, W.C.2. [Price 12*s.* 6*d.* net.]

Road Making and Road Using. By T. SALKIELD. Third edition. Sir Isaac Pitman and Sons, Limited, Parker-street, Kingsway, London, W.C.2. [Price 12*s.* 6*d.* net.]

Tenth Annual Proceedings of The Railway Fuel and Traveling Engineers' Association. 1946. The Secretary, The Railway Fuel and Traveling Engineers' Association, 327, South La Salle-street, Chicago 4, Ill., U.S.A.

A Manual of Time and Motion Study. A Practical Guide to the Measurement of Human Endeavour in Industry and to the Development of Productive Efficiency. By JOHN W. HENDRY. Second edition. Sir Isaac Pitman and Sons, Limited, Parker-street, Kingsway, London, W.C.2. [Price 12*s.* 6*d.* net.]

Newnes Engineer's Reference Book. Second edition. Edited by F. J. CAMM. George Newnes Limited, Tower House, Southampton-street, Strand, London, W.C.2. [Price 42*s.* net.]

Engineering and Technical Qualifications. Advisory Bureau for Research, 70, Victoria-street, Westminster, London, S.W.1.

Nigeria. Annual Report of the Public Works Department, for the Financial Year 1945-46. The Government Printer, Lagos, Nigeria. The Crown Agents for the Colonies, 4, Millbank, Westminster, London, S.W.1. [Price 9*d.*]

The Council of Ironfoundry Associations. Cost Ascertainment Methods for the Ironfounding Industry, Based on Uniform Principles. The Secretary, The Council of Ironfoundry Associations, Derbyshire House, Belgrove-street, London, W.C.1. [Price 42*s.*]

PERSONAL.

MR. W. C. CLEMENS, O.B.E., M.I.C.E., is retiring from the post of Divisional Road Engineer, Metropolitan Division, Ministry of Transport, on August 2. He will be succeeded by MR. G. H. HARGREAVES, M.C., B.Sc., M.I.C.E., the present Divisional Road Engineer for the Wales and Monmouthshire Division. To fill the vacancy in this latter Division, the Minister has appointed MR. J. F. A. BAKER, A.M.I.C.E., to be Divisional Road Engineer.

The Minister of Transport has appointed CAPTAIN J. C. TAYLOR, Principal Officer, Marine Survey Service, London District, to be Professional Officer of the Ministry at headquarters, in succession to CAPTAIN G. A. WILLIAMSON, who retired on July 27.

DR. C. DANNATT, O.B.E., M.C., M.I.E.E., who, as recorded on page 82 *ante*, has been appointed to succeed Mr. G. A. JUHLIN, M.I.E.E., as chief electrical engineer of the Metropolitan-Vickers Electrical Company, Limited, Trafford Park, Manchester, 17, has been elected to the board of the company. MR. H. PATERSON, M.I.E.E., manager of the Newcastle-upon-Tyne office of the firm and MR. C. PETERSEN, manager of the Manchester office, have now relinquished their duties and have been succeeded, respectively, by MR. A. J. CRAWFORD and MR. J. B. HARTLEY, M.C., M.I.E.E.

MR. J. N. KILBY, M.I.Mech.E., F.C.S., of Briton Ferry and Scunthorpe, consulting metallurgical engineer, has joined the board of the Blaenavon Company, Limited.

MR. C. F. J. LESLE, B.Sc. (Eng.), A.M.I.C.E., M.Inst.W.E., at present deputy engineer to the Tees Valley Water Board, has been appointed water engineer and manager of the water undertaking of the County Borough of Tynemouth.

MR. F. W. HIGGINS has been appointed managing director of the Carborundum Company Limited, Trafford Park, Manchester, 17, in succession to MR. A. D. KYSOR, who has retired after holding this position for the past 18 years. Both Mr. Higgins and Mr. Kysor have been connected with the Carborundum Company ever since manufacture was commenced at the Trafford Park works some 34 years ago.

MR. B. H. NEVARD has been appointed by the Admiralty to be Assistant Director of Navy Contracts and Assistant Director of Small Craft Disposals. He has also been appointed managing director of the Fairmile Marine Company, Cobham, Surrey.

MAJOR F. M. BERRYMAN, M.B.E., B.Sc. (Eng.) (Ind.), A.M.I.C.E., has been appointed to the Colonial Service as an executive engineer in Aden.

DR. THOMAS BARR, B.Sc., F.R.I.C., formerly in charge of a research section in I.C.I. Dyestuffs Division, has been appointed director of research to the British Hat and Allied Feltmakers Research Association, 12, St. Peter's-square, Stockport.

REAR-ADMIRAL P. RUCK-KEENE, C.B.E., D.S.O., has been appointed Director of Naval Training in succession to REAR-ADMIRAL J. W. DURNFORD, C.B. The appointment will take effect on August 8.

The whole of the shares of MESSRS. W. G. BAGNALL, LIMITED, locomotive designers and builders, Stafford, have been acquired by MESSRS. HEENAN AND FROUDE, LIMITED, Worcester. The new board of Messrs. Bagnall will comprise MR. ALAN P. GOOD (chairman) and MR. JAMES FIELDING, THE HON. A. C. GEDDES, MR. I. A. MARRIOTT, MR. CHARLES HILL and MR. W. O. J. URRY (secretary).

THE INSTITUTION OF BRITISH AGRICULTURAL ENGINEERS have removed their offices from Gordon-square to 68, Victoria-street, London, S.W.1. (Telephone: VICtoria 8237.)

As from August 5, MESSRS. CROMPTON PARKINSON LIMITED, will be occupying Astor House, Aldwych, London, W.C.2. The electric-vehicle division will remain at Electra House but, as from August 5, the telephone number, namely, CHAncery 3333; the telegraphic address, Crompark Estrand London; and the cable address, Crompark London, will be the same as those for Astor House.

A new association of interests between MESSRS. ALFRED HERBERT LIMITED, Coventry; the FELLOWS GEAR SHAPER COMPANY, Springfield, Vermont, U.S.A.; and the GEAR GRINDING COMPANY, LIMITED, Birmingham, has been announced. Messrs. Alfred Herbert Limited, who are agents for the products of the Fellows Gear Shaper Company, have been appointed sole agents, in the United Kingdom, for the sale of the Orcutt range of spur and helical gear-grinding machines, spline-grinding machines and measuring and testing equipment made by the Gear Grinding Company, Limited. By a reciprocal arrangement, this latter company have undertaken to manufacture Fellows products in this country, while the Fellows Gear Shaper Company will make Orcutt machines in the United States.

NOTES FROM THE NORTH.

GLASGOW, Wednesday.

Scottish Steel.—The works were on holiday last week and resumed on Tuesday morning this week with a greater volume of orders on hand than at any time within record. Plates, sections, and steel bars were booked out for months ahead, and the rather larger weekly quotas of regular consumers, such as shipbuilders, engineers, boilermakers, etc., are absorbing the bulk of the additional steel being produced since the coal shortage disappeared two months ago, so that, for ordinary market purposes, the supply stringency is as acute as it was before. Re-rollers are notably short of semies, and short-time working is still general. The sheet trade continues to be the busiest section of the whole market and the arrears of orders to be executed amounts to many months' work. Export business is again strictly limited, the turnover being less than one-third of the business offered. Pig-iron production has continued steadily throughout the holiday period, of course, and the stock position has improved considerably in consequence. Steel scrap is in good supply, though quality leaves much to be desired.

Scottish Coal.—The holidays have been negotiated without any appreciable inconvenience to coal consumers, and the miners have made a good re-start. House-coal stocks are low, however, and the tonnages in the depots are estimated at only two-thirds of the quantity on the ground at this time a year ago. Whether it will be possible to make good the deficiency during the latter part of the year is considered doubtful, though the Minister has stated that the stock shortage will be made good. Industry is comparatively well off for coal at the moment, the stocks of many users being equivalent to from three weeks' to six weeks' supply. Public-utility undertakings have managed to build up several weeks' reserve of fuel against winter contingencies, but the margin is still considered low for this purpose The persistent weakness in output (weekly returns are still 30,000 tons or more lower than before the five-day week started) is causing much uneasiness in all quarters of the industry. It is not expected that this deficit will be made up before next year at the earliest.

NOTES FROM CLEVELAND AND THE NORTHERN COUNTIES.

MIDDLESBROUGH, Wednesday.

General Situation.—The demand for larger deliveries of iron and steel is increasing in intensity and the serious deficiency in the total tonnage ouput is giving rise to long delays in the supplies to priority customers. The overwhelming demand for all commodities, both for home purposes and for the export market, is unabated. Producers have sold outputs as extensively as conditions permit and, in many cases, offers of new business have to be refused. The scarcity of pig iron is still hampering operations at the plants turning out descriptions of material which are urgently needed. Fuel distribution, however, is on an improved scale and all raw materials are obtainable in satisfactory parcels. Larger quantities of native ironstone could be used, but limestone is quite plentiful and adequate parcels of high-grade foreign ore are regularly reaching the consuming plants.

Foundry and Basic Iron.—The shortage of high-phosphorus pig iron is still restricting the output of light castings, for which there is a brisk demand in the building trade. There seems little likelihood of much increase in the deliveries of foundry pig to North-East Coast consumers, all of whom are entirely dependent on supplies from other producing areas. The basic-iron output is promptly absorbed by the makers' adjacent consuming works.

Hematite, Low-Phosphorus and Refined Iron.—The limited make of East-Coast hematite does not meet current requirements and there is an inconvenient scarcity of low- and medium-phosphorus grades of iron. Available parcels of refined iron are promptly taken up.

Manufactured Iron and Steel.—Semi-finished iron firms have substantial bookings and manufacturers of finished iron have a lot of work in hand. Some classes of semi-finished steel are in better supply than has been the case for some time, but the aggregate distributable tonnage is still inadequate. Home products are obtainable in moderate lots only and re-rollers are anxiously waiting for further consignments from abroad. Heavy billets and slabs are in fairly good supply but re-rollers are wanting to secure much larger parcels of small billets and sheet bars. The demand for all descriptions of finished steel is on a huge scale. Black and galvanised-sheet makers have commitments that preclude the discussion of new business, and plate-producers are fully sold to the end of the year; bookings for bars, sections, joists and rails also are exceptionally heavy.

Scrap.—Good steel scrap is in very strong request and there are keen buyers of all grades of cast-iron scrap.

NOTES FROM SOUTH YORKSHIRE.

SHEFFIELD, Wednesday.

Iron and Steel.—The heavy industries of Sheffield are at a standstill this week in consequence of the workpeople's annual holiday. Extensive overhaul of plant and machinery is in progress and the opportunity is being taken for expediting the progress of re-organisation of shops where changes in production are taking place. For some little time it has been considered advisable to devote more of the resources of heavy plants, formerly on armament work, to the production of railway materials which are in much greater demand on home and export account than the old resources of production could satisfy. This section of industry, among many others, is adversely affected by the shortage of steel supplies. The differences with steel melters on the agreement designed to bridge the week-end gap under the shorter working week, have not been settled. It is understood that the ballot of individual members of the 1,500 affected has confirmed the branches' vote not to operate the agreement. It is intended to expel the objectors from membership of the branches concerned and it is probable that the branches will be disbanded. It is estimated that the failure to operate the agreement entails a loss in steel production of 2,000 tons a week.

South Yorkshire Coal Trade.—Holidays have reduced the industrial demand for coal, but all users need larger deliveries if they are to build up their winter reserves to a safe level. The production of coal is below normal owing to holidays at pits and to absenteeism. High-priority users have had their requirements met, but others have had to go short. Gas coal is in strong request, and fuller allocations of coking coal are needed to make it possible to build up more the reserves of coke at depots and coke-works. Best washed smalls, and rough and nutty slacks are types of fuel in particularly heavy demand.

NOTES FROM THE SOUTH-WEST.

CARDIFF, Wednesday.

The Welsh Coal Trade.—Considerable interest was shown on the Welsh steam-coal market during the past week in the report that negotiations had reached an advanced stage for the shipment of a cargo of between 4,000 and 5,000 tons of coal to Huelva in North Spain. It was generally believed that the coal was for the Rio Tinto Company, and that, so far from signalising the resumption of foreign exports, it was merely a special arrangement under which a cargo of copper ore would be shipped in return. This will be the first shipment to Spain for a considerable time and one of the very few cargoes exported since the imposition of the ban during the fuel crisis last winter. The first cargo of United States coal to reach this country, since the conclusion of the recent agreement, has been unloaded at Swansea docks. It amounted to 9,000 tons, and it was reported that, by the end of October, a total of 47 cargoes would have been dispatched to various ports on this side of the Atlantic, bringing the total to over 400,000 tons. With holidays still curtailing outputs from the Welsh mines, conditions have been very difficult on the steam-coal market throughout the week. The demand on home account has been sustained at a high level, but as salesmen are hard pressed to maintain deliveries under existing bookings, the amount of new business that could be entertained was extremely limited. Bookings were already heavy over some time ahead. Exports were almost completely in abeyance. Once again the only coals that could be spared were limited quantities of the very poorest sorts which were being sent to Eireann users. Shipments of anthracites to Canada have been suspended during the month, owing to the interruption of outputs in the anthracite area by the miners' holidays. Bunker coals encountered a steady demand while patent fuel and cokes were difficult to secure.

Swansea Steel-Sheet Industry.—The market report issued by the Incorporated Swansea Exchange, 1, St. James's-gardens, Swansea, states that, last week, the tin-plate industry was more active and an increased volume of business was done, mainly with home consumers. In the export market, quieter conditions ruled and the sales were on a limited scale. Although the sheet mills are operating to near capacity, the pressure for supplies of steel sheets is unrelaxed and new business can only be placed for extended periods of delivery. The demand for iron and steel scrap is steadily maintained by steelworks and other consumers.

R.E.M.E. OFFICERS' ANNUAL DINNER.—It is proposed to hold the first annual dinner for R.E.M.E. officers, serving or otherwise, in London on Friday, October 31, 1947. Those who hope to attend are requested to make provisional application for tickets to Mr. G. O. Bell, M.B.E., War Office (M.E.3), Room 318, Golden Cross House, Duncannon-street, London, W.C.2, not later than Monday, August 18. The price of the tickets is expected to be about 15*s.* to 20*s.*

LAUNCHES AND TRIAL TRIPS.

S.S. "MARTIN CARL."—Single-screw general cargo vessel built by Messrs. S. P. Austin and Son, Limited, Wear Dock Yard, Sunderland, for A/S Dampskibsselskabet "Heimdal," Copenhagen. Main dimensions: 307 ft. by 45 ft. by 20 ft. 3 in. to main deck; deadweight carrying capacity, 3,400 tons on a draught of 19 ft. 1 in. Triple-expansion engine of reheat design supplied by Messrs. North Eastern Marine Engineering Company (1938), Limited, Sunderland, to give a service speed of 13 knots. Trial trip, July 2.

M.S. "RIO TERCERO."—Single-screw cargo and passenger liner built and engined by Messrs. Bartram and Sons, Limited, South Dock, Sunderland, for the Argentine State Merchant Fleet. Deadweight carrying capacity, 7,000 tons. Accommodation will be provided for 12 first-class passengers. Wallsend Slipway-Doxford oil engine of 5,250 brake horse-power, to give a service speed of 15 knots. Launch, July 18.

S.S. "FRANCISCO MATARAZZO."—Single-screw cargo vessel built by Messrs. William Gray and Company, Limited, West Hartlepool, for the Soc. Paulista de Navegaçao Matarazzo Ltda., Santos, Brazil. Main dimensions: 406 ft. by 56 ft. by 27 ft. 10½ in. to upper deck; deadweight carrying capacity, 8,920 tons on a draught of 25 ft. 0½ in. Triple-expansion engine developing 1,950 indicated horse-power, with two oil-fired boilers, giving a service speed of 10½ knots, supplied by the Central Marine Engine Works of Messrs. William Gray and Company, West Hartlepool. Trial trip, July 18.

M.S. "LAVEROCK."—Twin-screw cargo vessel built by Messrs. S. P. Austin and Son, Limited, Wear Dock Yard, Sunderland, for the General Steam Navigation Company, Limited, Trinity-square, London, E.C.3. Main dimensions: 245 ft. by 40 ft. by 15 ft. 3 in. to upper deck; deadweight carrying capacity, 1,400 tons. Five-cylinder Diesel engines of 800 brake horse-power to give a service speed of 13 knots, made by Messrs. British Polar Engines, Limited, 139, Helen-street, Govan, Glasgow, and installed by Messrs. North Eastern Marine Engineering Company (1938), Limited, Sunderland. Trial trip, July 23.

S.S. "MARENGO."—Single-screw cargo liner built and engined by Messrs. Swan, Hunter, and Wigham Richardson, Limited, Walker, Newcastle-upon-Tyne, 6, to the order of Messrs. Ellerman's Wilson Line, Limited, Hull. Main dimensions: 419 ft. 6 in. overall by 55 ft. 6 in. by 28 ft. 3 in. to upper deck; deadweight carrying capacity, 7,000 tons on a draught of 25 ft. 6 in. Triple-expansion engine with Bauer-Wach turbine and four oil-fired boilers. Trial trip, July 24.

S.S. "ATHENIC."—Twin-screw passenger and cargo liner, built by Messrs. Harland and Wolff, Limited, Queen's Island, Belfast, for Messrs. Shaw Savill and Albion Company, Limited, 88, Leadenhall-street, London, E.C.3. Main dimensions: 561 ft. overall by 71 ft. by 43 ft. 4½ in. to shelter deck; deadweight carrying capacity 11,000 tons, together with accommodation for about 80 first-class passengers. Parsons' triple-expansion single-reduction geared turbines, with two oil-fired water-tube boilers of the Yarrow double-flow side- red type, to give a service speed of 17 knots. Maiden voyage, July 31.

INTERNATIONAL ASSOCIATION FOR BRIDGE AND STRUCTURAL ENGINEERING.—The next congress of the International Association for Bridge and Structural Engineering, or the IABSE, as it is called, will be held during the first half of September, 1948, at Liége, Belgium. The matters to be discussed will include "Assembling Devices and Structural Details in Steel Structures"; "Developments in Building Structures in Concrete and Masonry"; "Development in Long-Span Steel Bridges"; and "Slabs and Various Curved Structures of Reinforced Concrete." Further particulars may be obtained from the secretary of the Association, at the Swiss Federal Institute of Technology, Zürich, Switzerland.

ASSOCIATION OF SUPERVISING ELECTRICAL ENGINEERS.—The Council of the Association of Supervising Electrical Engineers, 54, Station-road, New Barnet, Hertfordshire, announce the inauguration of the "A.S.E.E. Inventions Competition—Thurston Award," under which a cash prize of 10*l.*, given by Dr. A. P. Thurston, M.B.E., M.I.Mech.E., F.R.Ae.S., the Association's adviser on patents, will be awarded annually for the electrical invention submitted and considered to be the best in accordance with the rules of the competition. The competition is confined to the membership of the Association, and the prize will be awarded for the invention judged to be the most valuable contribution to the advancement of (*a*) the utilisation of electricity, (*b*) the improvement of distribution technique, or (*c*) the improvement of installation technique. The last day for the receipt of entries is Wednesday, December 31, 1947. An entrance fee of 10*s.* 6*d.* must accompany each entry and further particulars regarding the competition may be obtained on application to the secretary of the Association at the above address. All entries will be acknowledged by post.

EXHIBITS AT THE PUBLIC WORKS, ROADS AND TRANSPORT EXHIBITION.

(*For Description, see Page* 114.)

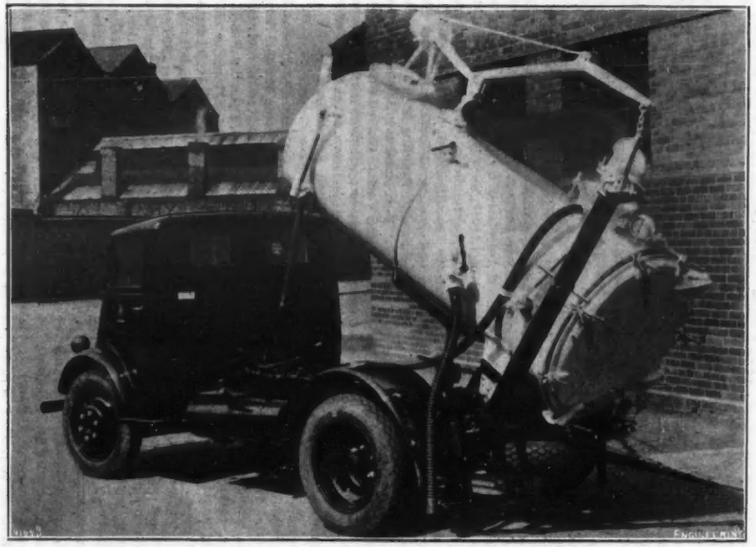


FIG. 1. 500-GALLON GULLEY AND CESSPOOL EMPTIER; FORD MOTOR COMPANY, LIMITED.

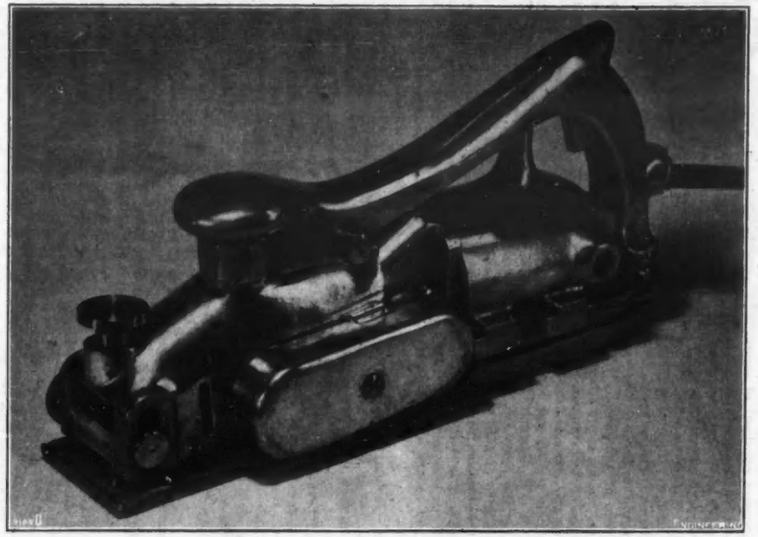


FIG. 2. PORTABLE HAND PLANER; MESSRS. G. & W. LOWE, LIMITED.

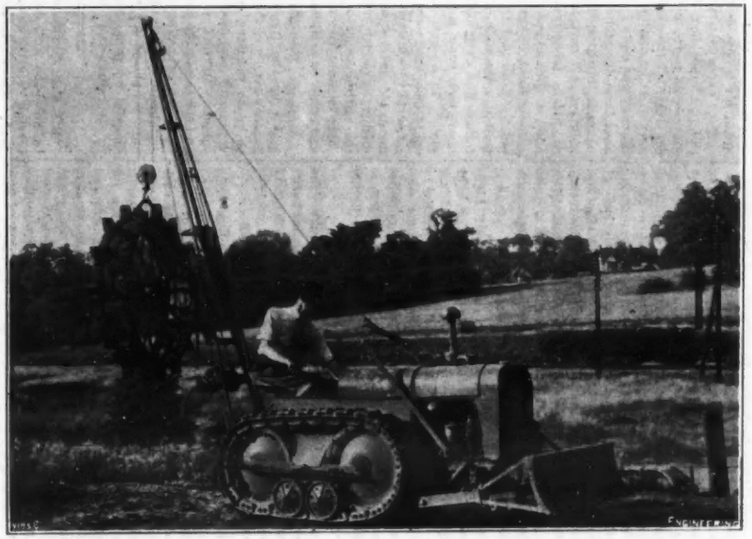


FIG. 3. COMBINED ANGLEDOZER AND CRANE; MONTGOMERIE REID ENGINEERING COMPANY, LIMITED.

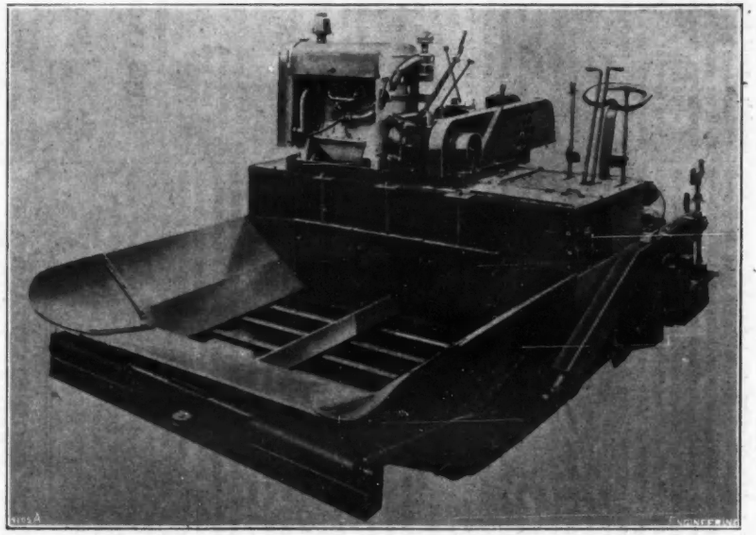


FIG. 4. ROAD FINISHER; MESSRS. BARBER-GREENE OLDING AND COMPANY, LIMITED.

ENGINEERING.

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Telegraphic Address:
"ENGINEERING," LESQUARE, LONDON.

Telephone Numbers:
TEMPLE BAR 3663 and 3664.

All editorial correspondence should be addressed to the Editor and all other correspondence to the Manager.

Accounts are payable to "ENGINEERING," Ltd. Cheques should be crossed "The National Provincial Bank, Limited, Charing Cross Branch." Post Office Orders should be made payable at Bedford Street, Strand, W.C.2.

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ADVERTISEMENT RATES.

Terms for displayed advertisements on the green art paper wrapper, on the inside black and white pages and in the buff art paper two-colour supplement, as well as for inserts, can be obtained on application to the Manager. The pages are 12 in. deep and 9 in. wide, divisible into four columns 2¼ in. wide. Serial advertisements will be inserted with all practicable regularity, but absolute regularity cannot be guaranteed.

The charge for advertisements classified under the headings of "Appointments Open," "Situations Wanted," "Tenders," etc., is 8*s.* for the first four lines or under, and 2*s.* per line up to one inch. The line averages six words and when an advertisement measures an inch or more, the charge is 24*s.* per inch. If use is made of a box number the extra charge is 1*s.* per insertion, with the exception of advertisements appearing under "Situations Wanted." Series discounts for all classified advertisements can be obtained at the following rates:—5 per cent. for six; 12½ per cent. for thirteen; 25 per cent. for twenty-six; and 33⅓ per cent. for fifty-two insertions.

TIME FOR RECEIPT OF ADVERTISEMENTS.

Classified advertisements intended for insertion in the current week's issue must be received not later than first post Wednesday.

"Copy" instructions and alterations to standing advertisements for display announcements must be received at least 10 days previous to the date of publication, otherwise it may be impossible to submit proofs for approval.

The Proprietors will not hold themselves responsible for advertisers' blocks left in their possession for more than two years.

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ENGINEERING

FRIDAY, AUGUST 1, 1947.

VOL. 164. No. 4253.

THE WATER POWER RESOURCES OF THE WORLD.

THE industrial development of Great Britain was built up on the use of coal and to a large extent the same thing is true of the industrialised countries of western Europe. In some cases, of which France, Sweden, Norway, and Switzerland are outstanding examples, water power now carries a large part of the load, either supplementing coal, as in France, or, in the absence of coal measures, forming the main source of power. At the present time, European countries in general seem incapable of mining sufficient of the coal which is available to meet the demand, Great Britain not being alone in this respect, and those which are able to rely to a major extent on hydro-electric supplies are in relatively favourable positions. It would be a council of despair to suggest that the present coal shortage in this country, and in western Europe, is other than temporary, although the temporary period seems likely to extend over an undesirably long time; both self interest and balanced judgment suggest that matters will ultimately rectify themselves. If they do not, the industrial outlook in the countries concerned is decidedly unpromising. Great Britain and Northern Ireland are stated to have 550,000 h.p. of developed water power and a total undeveloped potential of 700,000 h.p. These are not negligible figures and, although they fall far short of the power demand, compare favourably with those of Belgium, which has 32,000 h.p. developed and no reserves of any importance; Holland has 1,000 h.p. developed and a total potential of 25,000 h.p.

Power production is not the only purpose for which coal is required, and as there is no alternative for some of the uses to which it is put, the general tendency must be towards a constantly growing demand on water power. The rate of change-over will be checked if coal becomes available in larger quantities, but it may be doubted if increased mining activity could keep pace with the demand, in view of the fact that the power consumption per head of population is continually increasing; a rising installed horse power per employee is a characteristic of modern industry and the consumption of power in social services increases daily. In these circumstances, and taking very long views, it may be asked if the future will see a gradual transference of industrial activity, and its concomitant social prosperity, to countries well endowed with natural water power. A prospect of this kind would be singularly unfavourable for these islands, but it would not be eliminated by refusing to admit its possibility.

The question of the influence which natural power endowments may have, in the course of time, on the prosperity of various parts of the world is not a matter of interest merely to Great Britain. Even the United States and Canada, the countries which lead the world in installed waterspower plants, may ultimately be affected. The developed and potential water powers of North America total 116,000,000 h.p., but the corresponding figure for Africa is 274,000,000 h.p. No doubt many of the African sites are situated in remote and sparsely-populated areas, but a long course of years might see both of these conditions drastically modified. The above figures, and those quoted earlier, are taken from a return prepared by the United States Geological Survey. They are based on information obtained from consular agents, year-books published by foreign countries, and such other sources as it has been found possible to utilise. The return covers the whole world and it is realised that in some cases it may not be strictly accurate.

It relates to the situation at the end of 1945, but there is no reason to suppose that any great change took place in 1946. Even in Canada, a country in which progress in hydro-electric development has been very rapid, the Department of Mines and Resources reports only the addition of 27,760 h.p. in 1946. The figures for potential capacity which are given in the return, and which are quoted, are based on the ordinary minimum flow.

Reverting to the situation and prospects in western Europe, referred to in the first paragraph, it is of interest to compare the water-power resources of the east and west parts of the Continent. A convenient division between the two may be made by taking the countries which are attending the economic conference in Paris, which is considering the Marshall offer, as representing the west and the non-attendants as constituting the east. Although the division which has taken place is purely a political one, and certainly has no relation to power resources, it represents roughly a division of the industrial from the non-industrial countries. In as far as hydro-electric installations are a measure of industrial development, the industrial countries of the eastern group are Finland, with an installed capacity of 820,000 h.p.; Czechoslovakia, with 310,000 h.p.; and the Union of Soviet Republics, with 1,100,000 h.p.

The present installed capacity of the western group is 23,000,000 h.p., and its potential capacity 40,000,000 h.p. The eastern group, in which the Soviet Republics have been included, has at present hydro-electric installations totalling 3,000,000 h.p. and a potential of 26,000,000 h.p. The figures for the western group are increased to 24,400,000 h.p. and 46,000,000 h.p. if Spain is added. The fact that the installed capacity of the western group is nearly eight times that of the eastern forms, in a sense, a measure of the relative industrial developments of the two areas. The potential figures, although they indicate that great progress is possible in the east, do not suggest that the countries of that area are likely to be able, even in the long term, to supplant those of the west in the industrial application of power, the undeveloped capacity of the west exceeding that of the east by 16,000,000 h.p.

Considerations of this kind, when stated in general terms, may give a false picture even of far-distant possibilities. The 16,000,000 h.p. excess of undeveloped capacity, credited to the west, is represented exactly by the total water power of Norway, and it may well be that many of the sites at which potential power exists are so situated that they are not likely to be utilised in the general industrial development of any country. In the east, of the 26,000,000 h.p. of undeveloped capacity, 14,000,000 h.p. are situated in the Soviet Republics. From what is known of those countries, it appears possible that much of this potential may ultimately be utilised, but the activities of the great area they

represent are conducted behind such a veil of secrecy that speculation about their industrial future is largely vain. It may be that they will ultimately form one of the great manufacturing areas of Europe, maintaining normal trading relations with the rest of the Continent, but any such development is at present prevented by ideological notions with which this article is not concerned. Of the eastern nations, which, at least before the war, conducted their affairs in a manner permitting the development of international trade, Czechoslovakia showed the greatest industrial advance but there is nothing in the water-power situation to suggest that cheap and extensive power supplies will ultimately enable her to become one of the great mass-production centres; her total water-power capacity is less than that of Great Britain. Rumania is the country with the greatest undeveloped capacity, the total amounting to 3,000,000 h.p.; a long term of years may see great increase in the present development of 127,000 h.p.

It was pointed out earlier that the total capacity developed and undeveloped of Africa greatly exceeds that of North America, and Africa still has a lead of 89,000,000 h.p. when South America is added. The total for this latter sub-continent is 69,000,000 h.p., of which 29,000,000 is situated in Brazil. The reserves of that country approach in magnitude those of both the United States and Canada, and suggest that ultimately there may be some shifting of American industrial activity to the southern country. The United States has already developed 24,000,000 h.p. out of a total of 57,000,000 h.p., and Canada 10,000,000 h.p. out of a total of 40,000,000 h.p., whereas Brazil has an installed capacity of only 1,360,000 h.p. and reserves of 28,000,000 h.p. That Brazil has embarked on a process of development which may ultimately threaten the supremacy of the north is shown by the fact that her present installations have a capacity more than twice that of all other South American countries together.

In terms of continents, the second place in potential capacity is held by Asia, with a figure of 151,000,000 h.p. Of this, 64,000,000 h.p. is situated in the Soviet Republics, in which, however, present development is small, amounting to only 134,500 h.p. Ultimate progress may show remarkable changes in those countries, but it would appear likely that the energies of their central government will be mainly occupied with the development of the European part of their territory for many years to come. India is the Asiatic country in which the extensive utilisation of water power in a not very distant future may reasonably be foreseen. Industrialisation has already made a start and under the new regime which is being created, it is likely to be fostered. The reserves of the country (with Ceylon) amount to 39,000,000 h.p., and the developed sites only to 618,800 h.p. As would be expected, Japan heads the list in installed capacity, having stations of a total of 6,000,000 h.p. Reserves of 7,000,000 h.p. will allow of much future development, although in potential capacity the country is far surpassed by India and the Chinese Republic, which is credited with 22,000,000 h.p.

Oceania, the last great division of the world, has water-power plants of a total capacity of 1,300,000 h.p. and reserves of 20,000,000 h.p. New Zealand heads the list of installed plant, with a capacity of 819,000 h.p., Australia and Tasmania occupying second place with 250,000 h.p., and Java the third with 140,000 h.p. More than half the undeveloped capacity of the whole area is situated in Borneo, and although some of this may be developed it is difficult to think that it can have much effect on the industrial activity of the country or its near neighbours, in any foreseeable period. New Zealand, the Philippine Islands and Sumatra each have potential capacities of 2,000,000 h.p., and it is likely that further development will be seen in all of them. Australia is relatively poorly furnished in this respect, her reserves being given as 1,000,000 h.p. British interest in this part of the world has its counterpart in Africa, but of the enormous total capacity of that continent, a comparatively small proportion lies in British territory. The total is some 30,000,000 h.p., but there are 130,000,000 h.p. in the Belgian Congo and Belgian mandate, and 50,000,000 h.p. in the French Congo.

ROAD SAFETY AND ROAD ENGINEERING.

IT has been stated by Professor Patrick Abercrombie that the "science of road design to meet the requirements of motorised traffic is still in its infancy." It is doubtful if some American road engineers would share this opinion, and many of the same profession in this country might be inclined to say that it is not the science which is in its infancy, but its application. The road-traffic problem has various aspects, but the basic questions with which it is concerned are safety and convenience, the latter term, in this connection, referring to the fact that the trade and prosperity of the country are closely dependent on efficient road services for both goods and passengers. These cannot be provided without adequate roads, properly maintained. Present conditions in many large towns impose such a low speed on vehicles of all types that the value of the time lost amounts to a very high figure. Crowded roads also have a bearing on the question of safety.

Mr. A. J. Lyddon, who was formerly chief engineer to the Ministry of Transport, suggests that the factors affecting road safety may be divided under the three main headings: engineering, enforcement and education. The present loss of life and of serious injury, on the roads, are so great that any measures to reduce them are to be welcomed, and the activities of the Royal Society for the Prevention of Accidents, which gives much attention to the two latter of these factors, are worthy of every support. The instruction of school children in road sense and the pictorial campaign of the Ministry of Transport may be hoped to be of some effect, although the toll of the roads shows but small signs of reduction in magnitude. The re-introduction of driving tests is also to be listed among the measures designed to increase road safety by means of education.

The enforcement method takes the form of rules, regulations and instructional controls, the latter being represented, for instance, by the installation of traffic lights and the imposition of speed limits in selected areas. These two particular methods have proved generally successful; traffic lights are obeyed and although all vehicles may not always travel at 30 m.p.h., or less, in built-up areas, most drivers refrain from excessive speeds on controlled roads. One reason why these methods of traffic control by enforcement have been successful is that they are generally regarded as reasonable. It cannot be argued from them, as some would do, that the achievement of greater safety is merely a question of more regulations. When speed limits of 14 m.p.h., in 1896, and 20 m.p.h. in 1903, were imposed, they were not obeyed because they were unreasonable and ignored the growing importance and value of the motor vehicle in the national economy. An aftermath of this unenforceable control still survives in the regulation which prescribes that light vans shall not travel at more than 30 m.p.h. These vehicles are not more dangerous inherently than large motor cars, are usually controlled by more experienced drivers, and are generally engaged on more important activities.

The three aspects of road safety—engineering, education and enforcement—were referred to by Mr. Lyddon in in a paper entitled "The Highway Engineer and Road Safety," read at the Public Works, Roads and Transport Congress, London, on July 21. As will be clear from its title, the paper was concerned with the engineering aspects of the problem. It pointed out, largely by means of quotations from official reports on questions of road safety and layout, that safety could be promoted by the construction of by-passes, by the discouragement of frontal development on main traffic arteries, by restricting points of connection between such arteries and minor roads, by constructing dual carriageways, by building refuges at pedestrian crossings, erecting guard rails, and employing road-surfacing materials which do not become slippery when wet or worn. These various measures are all of an engineering character, but the putting of them into effect on a wider scale are matters of finance and administration over which the engineer, as such, usually has little control.

One of Mr. Lyddon's quotations was to the effect that "the avoidance of accidents depends to a large extent on the prudence and consideration shown by all classes of road users." This sentence brings the discussion back to questions of education and enforcement. Education is not being as successful as was hoped, and the fruitfulness of enforcement has definite limitations. The most profitable way of looking at the whole matter can only be attained by relating enforcement to engineering possibilities. The practicable procedure which is indicated by such relation has been cogently indicated by Sir Alker Tripp. He has pointed out that success in the reduction of accidents does not lie in instructing the police to operate further controls, which, in practice, are impossible to implement. Sixty per cent. of the persons killed in road accidents in London are pedestrians, and it has recently been suggested that this figure may be reduced by forbidding pedestrians to cross roads other than at selected or controlled crossings. This well-meaning idea would be impossible to carry out with road layouts as they are. Many, probably most, pedestrians would continue to cross roads at points selected by themselves and it would not be practicable to summon half the population.

The basic point made by Sir Alker Tripp is that the way to attain greater road safety and facilitate the flow of traffic is to adopt road layouts such that it is convenient, both for vehicles and pedestrians, to avoid dangerous situations and activities. In some cases, physical, not instructional, controls should be imposed. His suggestion that shopping centres and other much frequented parts of towns should be isolated in the form of "precincts" is well known and has been adopted in various town improvement and extension schemes. Through traffic would not enter these precincts, not because it was forbidden, but because it would be inconvenient and pointless for it to do so. The adoption of arrangements of this type is a matter for town planners rather than engineers, and in any case is hardly a question for the immediate present. Although Mr. Lyddon did not specifically make the point that controls imposed by physical means are more likely to be effective than those relying on rules and instructions, many of the measures he referred to clearly illustrate the point. Some of them need not be deferred to such a distant period as the adoption of precincts must be.

He stated, or quoted, that "dual carriageways should be constructed where an existing road carries, or a proposed road is expected to carry, 400 vehicles at the peak hour." This is an example of control by physical means. Many of the new arterial roads constructed in the years before the war are arranged for three lanes of traffic. They carry lavish instructions about keeping to the near lane except when overtaking, but, unfortunately, in too many cases the drivers of vehicles travelling in opposite directions decide to utilise the same part of the inner lane at the same time. Roads of this type can be rendered completely safe, as far as this type of accident is concerned, by constructing dual carriageways. If there is no inner lane, no accidents can take place on it. All this is obvious, but the point which does not seem to be generally realised is that the basic reason why dual carriageways are so desirable is that they impose a control which not even the most reckless driver can ignore.

When this point of view is realised, it can be applied advantageously to other dangerous aspects of present road layouts. A specific example may be instanced. A number of foot bridges have been built over the Kingston By-Pass, but it would hardly be an exaggeration to say that no one uses them, in spite of the fact that at busy periods the road is a death trap for individuals crossing. It would be useless to lay down a regulation that pedestrians must use the bridges, but if the carriageway were railed off so that the only way to cross the road was by the bridges, then accidents to pedestrians would be eliminated. No doubt there would be much grumbling, and the matter for administrators to decide would be the respective weights to be given to death and injury on the road and inconvenience to pedestrians. People do not complain because they have to use overbridges at busy railway stations, and the Kingston By-Pass at the peak of the traffic is more dangerous to cross than, say, the main line at Derby.

NOTES.

TERCENTENARY OF DENIS PAPIN.

FRANCE is honouring this year the memory of one of her famous sons, Denis Papin, the tercentenary of whose birth occurs in August and is being commemorated by a Comité Denis Papin, both in his native district and in Paris. England gave him refuge and he lived here more than 20 years, being elected a Fellow of the Royal Society in 1690, and his career is of particular interest to engineers because of his share in the development of the steam engine. The commemoration has been marked by several corrections of statements previously made about his life. In the first place, his birth was stated to have taken place at Blois, in the then Duchy of Orleans, but by the researches of Mr. Jean Chavigny it is now established that he was born in the farmhouse of the Papin family at Coudraies, a mile and a half from Chitenay, which is eight miles from Blois (Loir-et-Cher). The date formerly given for his birth, August 22, turns out to be the date of his baptism at Blois. One outcome of the commemoration was a village fête, at Chitenay, on Sunday, July 20, which included a procession and the unveiling by Professor A. Portevin, of the Académie des Sciences, of a tablet on his birthplace. The inscription on which is as follows: "Closerie des Papins/Dans cette maison serait né/Denis Papin en Août 1647/Offert par le Comité Denis Papin/20 Juillet 1947." The nearest equivalent in English of the uncommon word *closerie* is, perhaps, "small holding." The unveiling was followed by an *al fresco* lunch, presided over by M. Hermeloup, Maire of Chitenay, who was largely responsible for organising the fête. Among the foreign delegates who took part were Professor E. N. da C. Andrade, F.R.S., representing the Royal Society, and Dr. H. W. Dickinson, M.I.Mech.E., representing the Newcomen Society and the Institution of Mechanical Engineers. The lunch was followed by a play, illustrative of the life of Papin, written by Mr. Chavigny, and presented in the grounds of the Château de Chitenay. Later in the year there are to be ceremonies at Blois and at Angers (where Papin took his M.D. degree) and, in November, at Paris; a commemoration ceremony at the Sorbonne; and an exhibition of objects connected with the works of Papin, at the Conservatoire National des Arts et Métiers.

BRITISH AND METRIC STANDARDS OF MEASUREMENT.

A letter to a number of learned bodies and scientific institutions, signed by Sir Robert Robinson, President of the Royal Society; Sir Henry H. Dale, O.M., G.B.E., F.R.S., President of the British Association; Sir Edward V. Appleton, G.B.E., F.R.S., Secretary of the Department of Scientific and Industrial Research; Sir Charles G. Darwin, K.B.E., M.C., F.R.S., Director of the National Physical Laboratory; and Sir Clifford Paterson, O.B.E., F.R.S., chairman of the British Standards Institution Council, contains an appeal for greater uniformity in standards of measurement. The letter states that, in the course of the session of the Royal Society Empire Scientific Conference of July, 1946, devoted to the consideration of this question of greater uniformity in standards of measurement, the following resolution was adopted: "If text-books and scientific data or memoirs are expressed in systems other than the metric, conversion factors or the metric equivalent should be included." The object which it was intended to achieve by the resolution was to make British scientific papers more intelligible to overseas readers who are familiar with the metric system only. It is suggested that if councils or governing bodies of institutions or establishments, after considering the letter, are in general sympathy with the proposal contained in it, a meeting of representatives should be called, at which any special points of difficulty arising could be discussed, and, if possible, a fairly uniform system worked out. This could then be recommended to the publishers of journals and text-books. The letter adds that it is intended, as far as possible, to implement the resolution in the reports of the Department of Scientific and Industrial Research, published through H.M. Stationery Office, either by giving the metric equivalent of data expressed in British Units or by the provision of a table of conversion factors. The Royal Society are also proposing to implement the resolution in their own publications. It is requested that correspondence on the subject of the letter should be addressed to the Director, National Physical Laboratory, Teddington, Middlesex.

THE RAILWAY MUSEUM AT YORK.

For the greater part of the war period, the Railway Museum at York, which is maintained by the London and North Eastern Railway but houses also a number of exhibits contributed by the other British main-line railways and other lenders, has been closed; mainly, it is believed, on account of shortage of staff. On July 18, however, it was formally re-opened by Sir Ronald Matthews, chairman of the L.N.E.R., who was supported at the ceremony by a number of his co-directors and principal executive officers. Sir Ronald was introduced by Mr. C. M. Jenkin Jones, divisional general manager for the North-Eastern Area, who pointed out that the museum was, in effect, a national repository, as the other companies had asked the L.N.E.R. to include in it some of the most valued relics of the other lines. Sir Ronald, after remarking on the keen public interest in railways and their operation, drew attention to the wide scope of the Museum, which included not only historic locomotives and other rolling stock, the first iron railway bridge in the world, and an extensive collection of permanent-way material, but numerous small exhibits such as prints and drawings, though these were not housed under the same roof. The honorary curator of the museum is Mr. E. M. Bywell, who has been responsible for its restoration, and the exhibits are in the charge of Mr. J. H. Lister. The hours of opening are from 10 a.m. to 4 p.m. daily, except Sundays.

NORTH OF SCOTLAND HYDRO-ELECTRIC BOARD.

Steady progress is being made with the electricity distribution schemes of the North of Scotland Hydro-Electric Board and a number of contracts have been placed in connection with new generating plant, according to the annual report of the Board, recently issued. The report covers the year 1946, at the close of which nine distribution schemes had been put in hand or were approved, and eight more were under consideration by the Electricity Commissioners. As we have mentioned from time to time, still more are in course of preparation, which will provide an electricity supply to many new areas, including North Sutherland, the islands of Mull and Iona, the outer Orkney islands, and Caithness. The effect of the Board's work during the year, however, has been not only in the direction of improved amenities; as the report observes, the programme has now reached a stage where it is beginning to affect employment and the social conditions in the north of Scotland. The numbers employed on the schemes had risen to more than 4,000 by the end of the year, and is expected to rise to between 10,000 and 15,000 in due course. Construction camps to house in all 2,200 men have been provided on the sites of various schemes. The generating capacity of the hydro-electric plant ordered by the end of 1946 amounted to 374,000 kW; and major contracts for engineering works had been placed with 73 firms. To supply the distribution networks already approved for remote areas, and to provide current for constructional purposes, 56 Diesel-driven generating sets were bought or ordered, with an aggregate capacity of 17,500 kW. The erection of overhead lines has been hampered somewhat by shortage of materials, especially wood poles. The capital expenditure incurred during the year was 1,796,204*l.*, making a total, since the beginning of operations, of 2,129,514*l.*; but, as the total value of the schemes accepted by the Electricity Commissioners, up to the end of 1946, was nearly 9,300,000*l.*, it will be appreciated that developments in the near future should be considerable. It may be observed that the report, though a comparatively slim publication, is liberally illustrated with photographs, drawings and maps. It is obtainable from the offices of the Board, 16, Rothesay-terrace, Edinburgh, 3, and costs 1*s.* 6*d.*

OBITUARY.

MR. A. P. TROTTER.

ELECTRICAL engineers, especially those of the older generation, will learn with regret of the death, at the advanced age of 90, of Mr. A. P. Trotter, which occurred at Greystones, Teffont Ewyas, Salisbury, on Wednesday, July 23. Although he had been living in retirement for many years, Mr. Trotter will be remembered for his work on electrical units and standards and on illumination, as well as for the part he played in the development of electricity supply in its early days.

Alexander Pelham Trotter was born at Woodford, Essex, on June 25, 1857, and was educated at Harrow and Trinity College, Cambridge. While at Cambridge, he attended Clerk Maxwell's lectures on electricity, and took Second-class Honours in the Natural Science Tripos of 1879. A year later he was articled to Messrs. Easton and Anderson, and after serving an apprenticeship of three years with them, entered into partnership with Mr. W. T. Goolden, at Halifax, as manufacturers of electrical machinery, and, especially, of electric lighting equipment and searchlights for warships. He practised as a consulting engineer for some ten years, and for a time was technical secretary to the Electrical Trades Section of the London Chamber of Commerce. From 1890 to 1895 he was Editor of *The Electrician*. In 1896, he was appointed Electrical Engineer and Inspector to the Government of the Cape of Good Hope, but after three years in that position, returned to this country as Electrical Adviser to the Board of Trade. The 21 years during which Trotter occupied this post was a period of great development of electricity supply for all purposes, and it was his duty, as representative of the Government Department responsible for the administration of the cognate acts to ensure that this supply was given with due regard to technical efficiency and public safety. This duty he carried out with care and perseverance, and with an entire absence of that bureaucratic spirit which sometimes imbues the holders of such offices. It cannot be said, however, that he found the work congenial and after his retirement he indicated this fact by recording in *Who's Who* that his recreation was "remembering that he is no longer a Government official." Returning to professional practice, Mr. Trotter entered into partnership with Messrs. Handcock and Dykes as a consulting engineer, but after a short time retired finally from active service.

Mr. Trotter was elected an associate member of the Institution of Civil Engineers in 1883 and was transferred to the class of member in 1901. He had received the Telford Medal and Premium for a paper on "The Distribution and Measurement of Illumination." He became an Associate of the Institution of Electrical Engineers in 1884 and a Member in 1891. Subsequently, he served for a period as a member of the Council. He was a founder member of the Illuminating Engineering Society and served as its President from 1917 to 1921, during which period he was chairman of a committee concerned with special experimental work for the Ministry of Munitions. He was also chairman of a Joint Committee on Illuminating Engineering, appointed by the Department of Scientific and Industrial Research. He served as President of the Association of Supervising Electrical Engineers in 1916 and 1917, and was also a member of the Physical Society. For a time, Mr. Trotter was chairman of the Nomenclature Sub-Committee of the British Electrochemical Committee of the International Electrochemical Commission. He was the author of *Illumination, its Distribution and Measurement*, and of a number of papers dealing with his researches on photometry, prismatic glassware and other illumination problems.

MACHINE-CUT COAL.—In a written answer to Lieut.-Col. G. M. Sharp in the House of Commons on Thursday, July 24, the Minister of Fuel and Power (the Rt. Hon. E. Shinwell, M.P.) said that, in 1946, 74 per cent. of the total output of deep-mined coal in Great Britain was cut by machinery.

LETTERS TO THE EDITOR.

THE FUTURE OF PRECAST CONCRETE.

To the Editor of Engineering.

Sir,—Mr. D. A. Stewart's most interesting article, published in your issue of July 18, on page 51, might well be supplemented by a few words on the vast extension of scope of precast concrete made possible by the application of prestressed concrete. Precast prestressed concrete work falls into two categories. (1) Mass-produced small element. Sleepers, flooring joists and roof members, telegraph poles, high-pressure pipes, and beams for moderate-span bridges have all been manufactured by this process, producing savings in concrete and very large savings in steel by comparison with reinforced concrete. The use of careful granulometric and water-content control and the application of vibration, pressure and heat to the concrete has enabled excellent articles to be turned out ready for transport after a total time of two hours in the mould, and even less.

(2) The large structure composed of precast small elements. The ability to prefabricate large concrete structures in the factory with consequent control of quality and cost and to avoid the use of all but the simplest scaffolding on the site, when combined with the savings effected in steel and concrete, is a very remarkable advance. M. Freyssinet, in France, is at this moment prefabricating 12 river bridges, of 200 ft. to 300 ft. span, in a central factory; small precast elements are made up into sub-assemblies, shipped to the site on barges and hoisted into position. Not only do these bridges avoid all formwork and falsework in the river, save some 20 per cent. of concrete and 90 per cent. of steel by comparison with reinforced concrete work (wherever comparison is possible), but, in the case of the larger spans, actually show a saving in deadweight over an equivalent steel bridge.

This method has also been applied to aircraft runways, multi-storey building frameworks, tunnels in bad ground, grain silos, lighthouses, etc., as well as to small-span slab bridges prefabricated from precast blocks. All these structures have behaved perfectly under test. It is indeed difficult to see any limit to the application of this technique.

Yours faithfully,

A. J. Harris, B.Sc. (Eng.), A.M.I.C.E.
Société Technique pour
l'Utilisation de la Précontrainte,
5, Rue Beaujon,
Paris (8e).
July 22, 1947.

MAXIMUM THEORETICAL CO_2 IN FLUE GASES.

To the Editor of Engineering.

Sir,—With reference to the recent correspondence on the maximum theoretical CO_2 content of flue gases, it would appear that the second formula given by Mr. R. H. Parsons in your issue of June 6, 1947, on page 479, is not in agreement with that generally used by fuel engineers and given in Spiers' *Technical Data on Fuel*, page 314. The formula given by Mr. Parsons was:

$$M = \frac{21 \times (CO_2 + 0{\cdot}5\ CO)}{21 - (O_2 + 0{\cdot}105\ CO)}$$

in which M is the theoretical maximum CO_2 content of the waste gases and CO_2, O_2 and CO represent the percentages of the constituents in an actual analysis determined by means of the Orsat apparatus. Using the same nomenclature, the formula quoted by Spiers is:

$$M = \frac{21 \times (CO_2 + CO)}{21 - O_2 + 0{\cdot}395\ CO)}.$$

This formula may be derived as follows. Consider a dry flue gas of composition CO_2 a per cent., O_2 b per cent., CO c per cent., and N_2 $100 - (a + b + c)$ per cent. If the CO is now assumed to be burnt to CO_2 a mixture of the following volumetric composition will be obtained: CO_2 $a + c$ volumes, O_2 $b - \frac{c}{2}$ volumes, CO nil, and N_2 $100 - (a + b + c)$ volumes. The gas may now be regarded as consisting of the theoretical flue gas together with a proportion of excess air corresponding to the amount of oxygen $\left(i.e.,\ b - \frac{c}{2}\text{ volumes}\right)$ present. If this excess air is "removed" the volumetric composition becomes CO_2 $a + c$ volumes, O_2 nil, CO nil, and N_2 $100 - (a + b + c) - \frac{79}{21}\left(b - \frac{c}{2}\right)$ volumes. It will be seen that even if there is insufficient O_2 present in the original flue gas to burn completely all the CO to CO_2 the above composition will still be correct, since the term $\left(b - \frac{c}{2}\right)$ will have a negative value, indicating that additional O_2 (and, hence, its equivalent volume of N_2) must be added in order to obtain the theoretical flue gas.

Expressing this volumetric composition as a percentage, we get: theoretical CO_2 content

$$= \frac{a + c}{(a + c) + \left(100 - (a + b + c) - \frac{79}{21}\left(b - \frac{c}{2}\right)\right)} \times \frac{100}{1}\ \text{per cent.},$$

which, on simplification, gives:

theoretical CO_2 content

$$= \frac{21\ (a + c)}{21 - b + 0{\cdot}395},$$

i.e.

$$M = \frac{21 \times (CO_2 + CO)}{21 - O_2 + 0{\cdot}395\ CO}.$$

Yours faithfully,

C. Hulse.

Hadfields, Limited,
East Hecla Works,
Sheffield, 9.
July 22, 1947.

THE ENGINEERING PROFESSIONS AND THE INSTITUTIONS.

To the Editor of Engineering.

Sir,—Mr. J. H. W. Turner, in his article on page 447 of your issue of May 30, has drawn attention to what is potentially a very serious position, which, as he states, may lead indirectly to the decline of Great Britain from industrial pre-eminence to dependence on other formerly envious and hostile nations, and even to ultimate disaster. The root of success is in the men who carry it out, and technical ability follows or not as a corollary. First things first; our engineering institutions must realise that, unless they take action, an insidious rot, fatal to our national life, will set in too deeply to be counteracted. As Mr. Turner implies, there is little stimulus among those equipped with knowledge of the world to encourage recruiting to the engineering profession. The basic reason is the lack of remuneration. This is largely due to the exceptional arduousness of the profession itself—particularly that of the civil engineer—which has prevented engineers from finding time to advance their own interests by bargaining, and by entering public life and politics to the extent that their importance and status warrant.

My primary object in writing this letter, however, is to draw attention to the position in a more confined, but noteworthy, field, namely, in the armed Services. The remuneration in terms of pay and conditions of service now offered to engineers is less than other executives enjoy and compares still less favourably with those of other professions employed, such as doctors and dentists. For example, in the Royal Air Force officers in the engineer branch receive less pay in their rank than the others and, in addition, they may expect promotion at a later age. I believe I am right in saying that there is no compensatory element to cover this disability by a later retiring age. In the Royal Engineers, too, there is now no encouragement for prospective officers to join; owing to rules too involved to quote, the average pay of lieutenant-colonels, R.E., will be less than in any other branch of the Army. Promotion to the higher commanders' appointments (not administrative), judging from the last war, is barred for all practical purposes.

Until H.M. Government themselves show more appreciation of the services and hard work of their engineers, favourable reactions in other quarters are hardly likely. Surely, it is high time that the profession started to organise itself for the betterment of its conditions. The lead should be given by the engineering institutions, preferably by combining themselves for the purpose; and if they will not, an association should be formed, resembling those of the medical profession. It should be possible for the worst and vexatious aspects of trade unionism to be avoided. There should soon be plenty of able, comparatively young, and retired officers of personality available to organise the profession if civil engineers are not.

Yours faithfully,

Outpost.

July 18, 1947.

MOTOR TAXATION AGAIN.

By H. S. Rowell, O.B.E., D.Sc.

(*Concluded from page* 88.)

If Dr. Dalton and his three colleagues think that the British motor industry can compete with that of the United States as a result of the new flat rate of 10*l.* per car, even with the abolition of the purchase tax, then we are indeed in a serious case for leadership. Adam Smith pointed out, 170 years ago, that division of labour, a principle which had been applied for centuries before his time, could only be successful with a wide market. Those who have tried division of labour on a large scale know how perilous it can be without a wide and assured market. With all the vast tooling costs of mass production and the overhead charges involved in using them, the possible risks and losses with a falling market are catastrophic. This is one reason for the suffering of the United States during the great depression. Modern large-scale repetition manufacture needs a wide home market because in no other way can there be an assured and wide market.

In America, the home market for cars is not only fifteen times as great as that in Britain, but it is many times more exacting and more versatile. Thousands of miles of rough country, without railways, ranging from the tropics to the arctics, give the American designer a problem in transportation which few British designers have visualised and which, if solved, provides a world car. In Europe, and especially in Britain, there is not only a very temperate climate, but dense clusters of urban population, and finished roads centuries old, on which it would be uneconomic to use cars suitable for export to more primitive countries. In a city, the English baby car is supreme as a business vehicle. If a large home market is a *sine qua non* for efficient manufacture, as it is, and if the United States has a magnificent and unequalled home market for big motor cars, how can Britain compete with the Americans? Certainly not by copying their flat-rate tax and their type of car. Anyone who has studied this problem carefully knows that we can compete with the Americans in motor-car production just about as effectively as the Americans can compete with us in shipbuilding. The odds are not utterly hopeless, but they are very heavy and it is prudent to face them. Curiously enough, no one seems to ask the question why British commercial vehicles compete so successfully, both here and abroad.

In spite of all the discussions that have taken place during the past 170 years, few people seem to understand why manufacture needs a stable home market. Economists and Cabinet Ministers, in the past two years, have betrayed their failure to grasp this by no means elementary principle. When a car which is sold in this country at 500*l.* plus purchase tax is exported, the maker receives approximately 400*l.* or less, and the user, after transit and agency charges are settled, will pay something less than 500*l.* Thus, the motorist here pays about 660*l.* for the same car that is sold in an overseas market at about 500*l.* This compares favourably with the lot of the drinker of whisky, who may pay 3*l.* for a bottle that is exported for 5*s.*

and sold overseas for 25*s*. At first sight, it may seem wasteful to send cars abroad at a lower price than is charged at home, and one manufacturer has been heard to lament recently that he lost 100*l*. on every car exported.

Whether he loses on export cars depends on his home market, which is normally about six times his export market. Obviously, a manufacturer is in closer touch with his home market, and he can estimate more accurately what it will require, than can ever be the case in an export market. On this home information he can plan his output with certainty and, knowing his overhead charges, he can estimate what the selling price should be to give him a fair return. If now, by means of overtime, nightshift, piece work, or other extra drive on the bottleneck operations, he can raise his output beyond his budget, he can afford to sell his surplus at less than his home price and make increased profit. He dare not cut the price in the home market, but abroad he can do so safely. These extra sales cannot be unfair to the home motorist unless the cars are sold at less than prime cost, but the extra sales will bring profit to the manufacturer only if his home market is maintained. If the home market collapses, the expensive overhead organisation becomes a drain on his resources and no exports at less than the home price can yield a profit. From this point of view, it will be seen that an export drive, with a purchase tax at home, may seriously alter the usual balance of home and export trade and greatly complicate pricing arrangements. The present abnormal state of this country may require an abnormal disproportion of export to home trade, but it should be realised that the position is abnormal and not to be affected by infinitesimal variations in car taxation by means of a flat-rate car tax.

The inefficiency of the British motor industry as compared with that of the United States is by no means a new topic. For years it has been discussed and explained, and it is a healthy sign of anti-complacency that the matter should be discussed. One famous motor manufacturer, whose generous benefactions have made his name a hospital, if not a household, word, has ascribed the main trouble of the British motor manufacturer to high-priced steel. As there is not more than half a ton of steel in most of the popular cars, and since the price of steel in the United States is never more than a few pounds below the price in Britain, it is not easy to see how steel prices can be a factor of any importance. It is a common fallacy in all ages to ascribe all troubles to one cause; but, in most cases, there are several causes at work and to seize upon one of them obscures the others. To say that a flat-rate motor tax removes the last excuse of the British motor industry is over-simplification to the verge of dementia.

There is a further point of view which needs to be borne in mind, and that is future development. Why should politicians, however brilliant, presume to advise manufacturers and technicians on the kind of car that is required? Since 1919, cars have greatly improved, especially in regard to engine power, so that a 10-h.p. car to-day will travel as fast, and three or four times as far per gallon of fuel, as a 40-h.p. car could do 30 years ago. Roads are improving all over the world, cities are growing bigger in all countries, petrol is likely to become less plentiful, and should be less wastefully used, and so there is good reason for anticipating that the car of the future will have less than two litres of engine capacity and weigh less than a ton unladen. The British car to-day is the most efficient car for urban use in the world, and it has been developed by a band of pioneers in the teeth of gratuitous advice from amateurs to build big ugly high-riding cars with woolly engines. Even America, with ample cheap petrol supplies, has followed Britain's lead of high-duty engines and fuel economy and lower clearances.

In the discussion on the Finance Bill, Mr. Oliver Stanley seems to have discerned the facts of the matter with great clearness: "The task of competing with America in the export trade in cars," he said, "is not so simple as some Members would have the Committee believe. Mere alteration in the incidence of taxation is not enough. Sooner or later, it will be necessary to face the fact that it is impossible to get exports and revenue at the same time from the motor-car industry." Unless manufacturers of motor cars, iron and steel, and many other essentials are assured of adequate supplies of coal, and of labour that is not subverted by false ideals and artificially stimulated discontents, the outlook for the British motor industry is black; and to discuss trivial variations of taxation, while coal and other dominating factors threaten our industrial existence, is just foolish nonsense.

After the above was written, a letter by Lord Brabazon of Tara appeared in *The Times* of July 2, 1947, in which several ideas expounded above are very fully endorsed. Lord Brabazon goes farther, however, and puts forward the view that the old R.A.C. rating and horse-power tax kept out the big American car. With this the writer cannot agree; in fact, until some years after the Armistice of 1918, and before we had developed a good small car, Britain was flooded with big American cars and the Ford Model T sold in large numbers despite the 24*l*. tax. This was because it was cheap to buy. The intensive "Buy British" campaign of 1925 and thereabouts was brought in to meet the growing American competition and it helped, but only slightly. The main factor was that we could not afford the big cars from the United States when the British car was available, with its increasing efficiency and economy.

THE IRON AND STEEL INSTITUTE MEETING IN SWITZERLAND.

(*Continued from page* 90.)

WE continue below our report of the special summer meeting of the Iron and Steel Institute, held in Switzerland from July 9 to 19, and have now to deal with the first paper presented and discussed at the technical session of Friday morning, July 11, in the Auditorium Maximum of the Eidgenössische Technische Hochschule, the Swiss Federal Polytechnic, Zürich.

CREEP TESTING.

This was entitled "Observations on Conducting and Evaluating Creep Tests." It was by Mr. W. Siegfried, of Gebrüder Sulzer, A.G., who stated that the paper described sustained-load tests carried out on various highly heat-resisting alloys used in the construction of gas turbines. A much longer life was required of stationary gas turbines for power plants and marine-propulsion service than of aircraft gas turbines. In stationary plants this must be reckoned as ten years at least. The question of extrapolation was, therefore, of importance. This was best done by carrying out sustained-load tests to fracture and by following up the values for the most important physical properties by measurements made during the testing period, so as to obtain an idea of the stability of the structure. It had been proved that a number of factors permitted important conclusions to be drawn on the structural stability of a steel. Of great importance was the determination of reduction of area and elongation in the sustained-load test. Next came the determination of tensile strength, yield point, and reduction of area at fracture, at room temperature, of the specimens broken in the sustained-load test. Of importance also was the determination of the notch tenacity, at room temperature, of special small specimens which could be taken from the fractured bars. A study of the metallographic structure, as a function of time, also gave useful indications.

Mr. D. A. Oliver, in opening the discussion, said that the British approach to the whole subject was fundamentally different from that of the author. In Great Britain, when the effect of notches in turbine-blade roots was under consideration, metallurgists had recourse to photo-elastic studies, which, of course, gave a detailed solution only for the elastic case. This was regarded as giving guidance, and was not looked upon as a final answer. When it came to the question of studying an actual blade-root fixing, they felt that it was misleading to deal only with one blade dummy and one root fixing. It was necessary to consider at least two blade-root fixings on each side of a single blade under test. It would be interesting to know whether the author had found this necessary, because there would be violent lateral reaction the moment the blade tried to pull out. Hence, if the actual reaction conditions had not been simulated a false result might easily be obtained. Either the fixing would be too stiff, or, if the test-piece had been made too narrow, there would be insufficient lateral strength and the result obtained would be unduly pessimistic. The general method of analysis, using an S-curve, was a somewhat new method of approach and would have to be carefully considered.

Mr. W. E. Bardgett referred to investigations by a sub-committee of the British Electrical and Allied Industries Research Association on the failure of 0·5 per cent. molybdenum-steel steam pipes. As a result of the investigations, he said, it was recommended as highly important that pipes should have smooth and undamaged surfaces, and that grooves, fissures, indentations, hammer marks and other irregularities which would cause stress concentrations should be prevented or removed. Probably in no field of engineering was co-operation more necessary than it was in the high-temperature field; from the designer's point of view, on account of the necessity of having the right type of data, and from the producer's point of view because he should know precisely what type of information was required, on account of the time-consuming nature of the tests. Agreement between the producer and the user was obviously most necessary. The author had made the interesting suggestion of identifying the most important physical property which could be measured directly in a suitable manner, and was directly related to the change in condition affecting high-temperature behaviour. This was to be applied as a check on the reliability of extrapolation of sustained-load curves. This indirect method would require a very complete understanding of the high-temperature characteristics of a material to be applicable with sufficient certainty, and it was doubtful whether any shortened form of test would be of direct assistance in guaranteeing safety in machines, though it might well serve as a guide in the selection of materials for further investigation.

Dr. L. Jenicek stated that the classical creep test which gave useful information concerning the conditions in a boiler, for example, was not sufficient for the solution of the problem of the gas turbine, where it was necessary to use the combined fatigue test and corrosion test. Dr. C. Sykes, F.R.S., who closed the discussion, stated that there was so much work which had to be done on creep-testing machines at the present time that, if some of the variables involved could be investigated without using creep machines, other variables, such as the notch effect, could be dealt with more expeditiously. That the problem of creep was complex was further emphasised by the following example. An experimental steel tested at his laboratory had quite a small elongation and reduction of area when tested cold in a tensile machine; in other words, at room temperature, there was no necking. At elevated temperatures, however, substantial necking occurred. Moreover, no major cracks appeared; any cracks which started seemed to seal themselves up a very short distance inside the specimen. It might be imagined, therefore, that this material was not notch sensitive; yet its fatigue properties, when notched, were in no way superior to the fatigue properties of other materials which showed marked intercrystalline cracking in ordinary creep testing.

The author intimated that he would reply in writing and the meeting passed on to the next matter on the agenda.

(*To be continued.*)

MACHINE TOOL AND ENGINEERING EXHIBITION, LONDON, 1948.—The Machine Tool Trades Association, Victoria House, Southampton-row, London, W.C.1, are to stage an international exhibition at Olympia, London, W.14, late in August, 1948. It will be called the Machine Tool and Engineering Exhibition, London, 1948, and will be the first exhibition of its kind to be held in London since the Association's exhibition at Olympia in 1934. Further details will be issued in due course.

PUBLIC WORKS, ROADS AND TRANSPORT EXHIBITION.

As briefly recorded on page 86, *ante*, the eleventh Public Works, Roads and Transport Congress and Exhibition was opened at Olympia, London, on Monday, July 21, by the Prime Minister (the Rt. Hon. C. R. Attlee, M.P.), and remained open until Saturday, July 26. This exhibition, which before the war was held every two years, was staged at Olympia for the first time, but the space occupied by the stands was approximately the same as that taken up by previous exhibitions at the Royal Agricultural Hall. There were 140 exhibitors who, between them, showed a great variety of equipment and materials, ranging from large vehicles to street-lighting fittings and from constructional steelwork to plastics. Surveying instruments also found a place, while the displays on the stand of the Department of Scientific and Industrial Research enabled visitors to learn something of the work of the Road Research Laboratory at Harmondsworth, which is studying the problems that arise in designing, building and maintaining public highways, and of the Building Research Station, at Watford, which is carrying out research on building materials and processes.

Among the exhibits of engineering interest mention may be made of the 500-gallon combined gulley and cesspool emptier, which is illustrated in Fig. 1, on page 108. The chassis of this vehicle, which is of the 4-ton Thames type, was constructed by the Ford Motor Company, Limited, Dagenham, Essex, and the body by Messrs. Tuke and Bell, Limited, Carlton Engineering Works, Lichfield, Staffordshire. The wheelbase is 9 ft. 10 in., the front and rear tracks being 5 ft. 3½ in. and 5 ft. 5 in., respectively. It has a turning circle of 44 ft. 9 in. and the overall dimensions are 17 ft. 1½ in. long, 6 ft. 10 in. wide, and 9 ft. 10 in. high. It is fitted with a 30-h.p. V-8 engine. As regards the body, the receiver is of welded construction and consists of two compartments, one of which is designed for carrying 200 gallons of clean water, while the other, which is at the rear and is fitted with a hinged rubber-faced door, holds 300 gallons of sludge. This receiver is emptied by a rotary exhauster, which is driven by a power take-off on the gearbox. Reversing valves are provided on the system so that, if required, a pressure can be obtained. A float valve is fitted in the top of the sludge compartment thus, it is claimed, making it impossible for liquid to be drawn into the air pump when the receiver is full. This system is also fitted with a relief valve, which is set to blow off at a pressure of 10 lb. per square inch, while contents gauges are provided on both the tanks. The suction valve, which is of simple design, is hand-operated and provides a full-way bore when open. We understand that it is easily dismantled for inspection and for the replacement of the rubber face when this is necessary. As regards other features, the swivelling jib is fully balanced, and is designed for easy operation from either side of the vehicle. The tipping gear is of the mechanical-hydraulic type, and enables the tank to be moved through an angle of 30 deg. Clean-water re-sealing is carried out through a hose fitted to both sides of the vehicle. This may, if desired, be effected under pressure. The armoured hose which is provided for emptying cesspools is 3½ in. in diameter and is controlled by quick-acting inlet and outlet valves. It can be cleaned under pressure by means of the power take-off mentioned above.

The great attention which has been paid in recent years to the production of power-driven hand tools for woodwork may be illustrated by referring to the portable hand-planing machine which was exhibited by Messrs. Thos. Firth and John Brown, Limited, Sheffield. This planer was manufactured by Messrs. G. and W. Lowe, Limited, Sheffield, and is illustrated in Fig. 2, on page 108. It has been developed to meet as many requirements as practicable with the one tool, and as a consequence it can be used for rabbeting, moulding and slitting, as well as for straightforward planing. It is operated by a ½-h.p. universal motor, which runs at 15,000 r.p.m. This motor is connected directly through a worm and worm wheel to the cross shaft of a small gearbox, which forms an integral part of the motor unit. The worm and wheel reduce the speed of the cross-shaft to approximately 4,500 r.p.m. The drive is transferred from the cross-shaft to the cutter spindle through a roller chain and sprockets, the chain case for which is visible in the illustration. The depth of cut is controlled by a single nut graduated in thousandths of an inch, the nut being situated at the front of the plane. The cutter spindle carries a 3-in. diameter by 2-in. face multi-blade cutter and is located on two self-aligning ball races which are totally enclosed in their respective housings. Axial adjustment of the spindle is provided by fitting the ball races to housings having an eccentric adjustment of $\frac{1}{64}$ in. The accessories provided with the planer comprise a rabbeting shoe and cutters, moulding cutters and a slitting saw. The rabbeting shoe replaces the usual planing shoe, but has a long narrow mouth which permits the rabbeting cutter to project and produce rabbets up to ½ in. in depth; an adjustable fence is provided for use in conjunction with the rabbeting shoe. Similarly, moulding cutters are used in conjunction with the rabbeting shoe and fence, the maximum depth of moulding being approximately ½ in. As previously mentioned, a 4½-in. diameter slitting saw also has been developed. This permits a cutting depth of some ⅞ in., and, as in the case of the rabbeting and moulding cutters, fits on to the common spindle. An interesting feature of the plane is the provision of two switches, one in the main handle and another in the forward hand rest. These are arranged so that the machine cannot start until both switches are depressed.

The Bristol crawler tractor was first designed for agricultural work, and as such has been described from time to time in ENGINEERING. During recent years, however, equipment has been developed by the Montgomerie Reid Engineering Company, Limited, Basingstoke, which renders the tractor suitable for industrial purposes as well. Three separate items of equipment were exhibited, namely, an angledozer, a rear-mounted skip, and a rear-mounted crane. The tractor is illustrated in Fig. 3, on page 108, where it is shown fitted with the angledozer and crane. The blade of the angledozer is pinned at its centre to the front of a subframe, which embraces the front of the tractor and is pinned on each side to the tractor chassis. The blade is located by struts, which run backwards from the two ends of the blade to the subframe. The struts are pinned to the subframe, three positions being provided for the pins on each side, so that the blade can be held parallel to the front of the tractor or angled in either direction. The complete blade and subframe can be lifted by operating a hand lever adjacent the driver. The lifting linkage also incorporates a means for adjusting the depth of cut. As, obviously, there is a tendency for the front of the tractor to dip when the blade is at work, a single castor wheel is provided below the front of the tractor for steadying purposes. The crane, like the angledozer, is fitted to the tractor by pins only, and the complete assembly can be removed or replaced in a few minutes. The jib is carried on a small subframe. This slides over an extension which is bolted to the rear of the tractor chassis, while the subframe is locked to the chassis extension by the insertion of vertical pins. The jib is held in the upright position by a guy rope. This passes over a pulley which is fitted to the top of the jib and then down to a stirrup piece which embraces the engine casing. The ends of the stirrup are pinned to the tractor chassis and the rake of the jib is adjusted by shortening or lengthening the guy rope, an operation that, we understand, can be performed from the driver's seat. The load is lifted by a manually-operated winch fitted to the jib, and is sustained by a ratchet device. The length of the jib is 12 ft. and the maximum safe load is 8 cwt. The skip is secured to the rear of the tractor in a similar manner to the crane. It is also fitted with a subframe which slides over the chassis extension. Its capacity is between 7 and 9 cub. ft., and by manipulating a simple system of levers it can be made either to dump its load or spread it. When the load is to be dumped, the skip is turned upside down, but when the load is to be spread, a narrow door in the bottom of the skip is opened.

A wide variety of refuse-collecting vehicles were on show at the exhibition. Perhaps the most interesting of these was the ground-loading vehicle exhibited by Messrs. Glover, Webb and Liversidge, Limited, 561, Old Kent-road, London, S.E.1. This vehicle is interesting, however, not so much for the method of refuse collection used as for its general design. The construction is "chassisless" and the drive is through the front wheels. By adopting this arrangement, it is claimed that it is possible to produce a rear-loading machine without the complication of steps, mechanical hoisting gear or other loading devices. An all-steel moving floor is incorporated, which is power driven and fitted with an overload clutch so that it can be used for load packing. The capacity of the main compartment is 12 cubic yards, while salvage bins and a paper compartment, with capacities of 48 and 80 cubic feet, respectively, are provided. The vehicle is powered by a Meadows four-cylinder overhead-valve petrol engine, with a capacity of 3,686 c.c., and developing 59 brake horse-power. The drive from this engine is taken through a single dry-plate clutch to a four-speed gearbox and thence to a spiral-bevel type of front axle. The gearbox is coupled directly to the front axle, which is fitted with fully-floating half shafts, a bevel-pinion type differential and Rzeppa constant-velocity universal joints. The moving floor consists of rust-proofed steel slats linked together in such a way that the heavier the load, the tighter the joints become. The slots are mounted on a Reynolds conveyor-type chain and the front of the floor is fitted with a steel bulkhead, which is used to compress the load against the tail-board before it is moved forward. The operation of this floor is controlled from the driver's seat, and when the refuse is being compressed, an automatic slipping clutch comes into operation once the maximum safe load has been reached. The overall length, width and height of the vehicle are 22 ft. 3 in., 7 ft. 5½ in., and 7 ft. 8 in., respectively, while the ground clearance is 11 in.

Another vehicle in this class was the dustless refuse collector exhibited by Messrs. Shefflex, Limited, Rutland-street, Sheffield, 3. This consists of a totally-enclosed body, which is mounted on a standard Dennis "Pax" chassis. The bins are placed on a cradle near ground level at the rear of the vehicle and are then raised mechanically so that their contents can be emptied through an automatically controlled dustless shutter.

Messrs. Barber-Greene Olding and Company, Limited, Hatfield, Hertfordshire, were exhibiting a bucket loader, a coal loader and a road-finishing machine. Of these three machines, probably the most interesting is the road finisher, which is illustrated in Fig. 4, on page 108. The purpose of this machine is to receive bituminous materials from lorries and to lay the material to the required thickness in continuous strips, the widths of which may be varied between 8 ft. and 12 ft. The machine also compacts the material, giving it a smooth surface and, if required, it can be set to lay the material at a camber. Tipping lorries loaded with the bituminous material can be backed on to the front of the machine so that the rear wheels make contact with rollers which are fitted to its front. These rollers are visible to the left of Fig. 4. The machine is self propelled and pushes the lorry along while the contents are being tipped into the hopper at the front of the machine, thus making it unnecessary to stop the machine while it is being loaded. The material is fed from the hopper by conveyors, which are fitted with cross bars, to spreading screws, which distribute it uniformly across the width of the machine and in front of the tamper. The tamper can be compared to a horizontal rectangular bar with its major axis set in the vertical plane. It has a vertical stroke of ⅛ in., and it strikes-off and compacts the material to the desired thickness, while the screed, which is directly behind the tamper, smooths and "irons" the surface ready for final compaction by rollers. The screed plates are fitted with a heating unit so that they can be warmed for dealing with tacky materials which tend to stick to the plates.

(*To be continued.*)

RECENT DEVELOPMENTS IN POWER-STATION PRACTICE.*

By F. W. LAWTON, M.I.Mech.E., M.I.E.E.

(*Continued from page 79.*)

OWING to the increased regenerative feed heating with high pressures, travelling stoker or chain-grate operation becomes difficult if the primary-air temperature exceeds 350 deg. F., and generally it is desirable that this temperature should not exceed 300 deg. F. On this basis, it would appear that a pressure of 900 lb. per square inch is about the limit for stoker firing. On the other hand, pulverised-fuel firing imposes no such limits. The problem is rather to produce air sufficiently hot (in the neighbourhood of 500 deg. to 600 deg. F.) to dry the high moisture content coal supplied. To meet this requirement it has generally been found necessary to split the economiser and air heater into two sections and sandwich them. Almost invariably British manufacturers prefer to locate the superheater, even for the highest temperatures, in the convection zone of the boiler plant. Experience has not encouraged the use of radiant superheaters located in the furnace. The draining superheater is gradually replacing the non-draining type, and it is now appreciated that the advantages of a draining superheater during starting-up outweigh the constructional advantages of the non-draining type.

For temperatures up to 850 deg. F., plain carbon steel is used. Above this, however, plain carbon-molybdenum steel is used up to temperatures of 950 deg. F. Above these temperatures chromium steel may be employed. The high steam temperatures now adopted demand constant superheat over a large range of load. War-time experience has shown that varying fuels can affect the steam temperature appreciably, even at uniform load, due to variations in combustion. Quite apart, therefore, from any considerations of maintaining steam temperatures over a given range of load, it is necessary, particularly where high steam temperatures are involved, to ensure against a pre-determined temperature being exceeded. In this country, control is achieved mainly by by-passing the gases through the superheater by temperature control or by de-superheaters, or a combination of both. The most notable feature of modern boiler plant is the extensive use of the steaming economiser. In practice, this economiser replaces boiler convection surface more advantageously because of the higher rates of heat transfer that are possible.

Two large capacity pulverised-fuel fired boiler units are now under construction in this country for evaporations above 500,000 lb. per hour, whereas in the United States, out of a total of 50 recent units, two are of 1,000,000 lb. per hour or over, 13 in the range 500,000 lb. per hour to 850,000 lb. per hour, eight in the range 350,000 lb. per hour to 500,000 lb. per hour, and 27 below 350,000 lb. per hour. This high proportion of small units is rather remarkable.

As regards the practice of reheating the steam, there appears to be little disposition to proceed with this on any appreciable scale. Two important plants are under construction in this country, notably at Littlebrook "B" and Dunston "B." Both these plants represent a slight advance over previous installations, in that the steam and reheat temperatures are 850 deg. F. In the United States, Port Washington and Twin Branch represent the outstanding examples of the use of the reheat cycle, and it is interesting to note that the most recent extension at Twin Branch is with a straight condensing cycle. In general, there is a distinct tendency in America towards a pressure level of around 950 lb. per square inch, the temperatures varying from 900 deg. to 950 deg. F. A reasonable amount of experience has been obtained in this country with operation at steam temperatures in the region of 900 deg. to 960 deg. F., and with the advances in metallurgy there seems to be no reason why these temperatures should not be increased, with a corresponding pressure level of the order of 1,000 lb. to 1,150 lb. per square inch. Having regard to the large temperature and pressure ranges now possible, it would seem highly desirable that standardisation of terminal steam operating conditions and also boiler sizes should be made, as this would undoubtedly lead to uniformity which would assist and cheapen construction. There seems to be no logical reason for insisting on minor differences of steam pressure or temperature, which give rise to unnecessary complications.

Steam soot-blowing continues to be the general medium adopted in this country for on-load cleaning, though a number of stations supplement this with water lancing, either by hand operation or with automatic gear. Considerable progress has been made in understanding the necessity of a proper study of blower location in relation to the surfaces to be swept and the use of remote control of blowers, either for individual operation or automatic sequence, has enabled blower locations to be selected with a freedom unknown in the days of manual control. It is reasonable to assume that remote blower operation will become a permanent feature in English boiler practice.

The use of automatic boiler control has increased considerably in the past ten years and is now a feature of many of the large stations in this country. Instrumentation has also considerably increased in this period. While the initial cost of control gear amounting to about 0·02 per cent. of the cost of the boiler unit is not large, it is doubtful if any increased thermal performance is possible over that obtained from a well-trained and keen operating staff supplemented by such items as automatic furnace-draught control and remote operation of auxiliary drives. A number of unified boiler controls on the Ward-Leonard system are, however, in service in this country.

With modern boiler plants the necessity for clean steam is now fully recognised. This is essential for the prolongation of the life of the superheater, and for avoiding fouling of the turbine blades with the consequent reduction in output capacity and availability. Attention has been directed to the steady water level in the boiler drum and the disposition of the return risers from the furnace walls. Modern drums are provided with steam scrubbers, the design of which has not changed appreciably for some years save in matters of detail, and in addition steam receivers have been fitted on many boilers as an additional safeguard. In normal power station operation make-up requirements are of the order of 2 per cent., and treatment of the raw water for make-up generally involves straight evaporation; preliminary softening by lime-soda or zeolite, or both, followed by evaporation. The chemical treatment does not remove silica or organic matter. Proper conditioning implies treatment of the water in the feed and boiler system to obtain optimum qualities for prevention of scaling of the heating surfaces, and prevention of corrosion in feed pipes, and auxiliary equipment constructed of both ferrous and non-ferrous materials, and the boiler proper. The feed system may be protected by complete degasification, more particularly in regard to oxygen. Main condenser de-aeration of condensate and mechanical de-aeration of make-up is usually sufficient for the lower pressures. For higher pressures this process may be augmented by the process known as scavenging. This is a chemical process involving fixation of residual oxygen by means of an oxidisable chemical of which several are available, such as sodium sulphite. Adjustment of *p*H is advisable in power station practice. In general, power station feed water is particularly pure and at the high temperatures of the feed system contains an appreciably higher hydrogen-ion concentration. *p*H adjustment is accomplished by alkalisation or boiler blow-down where necessary. The de-oxygenated conditioned feed may arrive at the boiler contaminated by condenser leakage and carry forward a slight but cumulative quantity of scale-forming salts. The boiler water must therefore be capable of acting as a buffer to ensure that these scale-formers are rendered non-scale forming. Normal power station conditions require a reagent which will not be decomposed at the existing temperatures. Sodium phosphate is such a reagent. It is usual also to provide a buffer against abnormal oxygen ingress. Sodium sulphite in small concentration satisfies this need. The alkalinity conditions of the boiler water must be so adjusted for optimum conditions of corrosion prevention and inhibition of scale formation. Concentrations must be maintained below the carry-over threshold peculiar to the boiler. In certain circumstances it may be advisable to operate with potassium salts instead of the usual sodium salts to prevent scaling.

It has now been established that to suppress the dust nuisance from power-station chimneys some form of dust-arresting apparatus must be installed. The chimneys also must not be less than 2½ times the height of the power station roof or adjacent buildings, in order that any dust leaving them may be discharged into an undisturbed air stream which gives a high degree of dispersion to the dust. Chimneys in hilly districts must receive special consideration as the surrounding hills may create a downward flow of air which would necessitate them being made higher than the empirical 2½ times (minimum).

It has always been considered that even with high chimneys pulverised fuel-fired boilers must be equipped with dust-arresting apparatus, since at least 70 per cent. of the ash in the fuel might otherwise pass to the atmosphere and result in a dust emission of 2·8 grains to 3·5 grains per cubic foot of gas leaving the chimney when burning a coal containing 15 per cent. of ash. With stoker-fired boilers, however, it was at one time considered that dust arresters might not be necessary if high chimneys were used as the amount of dust emission would only be equivalent to about 10 per cent. of the ash in the fuel. This would result in a dust emission of only 0·4 grain to 0·5 grain per cubic foot of gas leaving the chimney when burning coal of an ash content of 15 per cent. Experience during the last twenty years has proved, however, that even such relatively low concentration constitutes a definite nuisance and furthermore, that modern high-duty stoker-fired boilers may produce a quantity of dust equivalent to about 35 per cent. of the ash in the coal. Dust arresters and high chimneys have therefore become a necessity for stoker-fired boilers.

The factors which govern the concentration and the nature of dust in flue gases are: the method and rate of combustion of the fuel; the design of the boiler plant and flues; the ash content and the nature of the ash in the fuel; and the combustion characteristics and size of the fuel.

Dust from pulverised fuel-fired boilers is very fine. About 80 to 90 per cent. is 63 microns or less in diameter, and 75 to 85 per cent. is 25 microns or less. It is composed mostly of spheres and cenospheres which, due to their fineness, are readily carried in gas streams, whereas dust from stoker-fired boilers has only 30 to 40 per cent., which is 63 microns or less, and 10 to 25 per cent. of 25 microns or below. As the latter dust is mostly of the nature of coke particles, it should be more correctly described as "grit." This is very abrasive and could cause considerable inconvenience and nuisance if deposited in relatively small quantities in industrial areas where delicate work is carried out, or in residential areas. Tests that were carried out some time ago on a stoker-fired and a pulverised-fuel boiler with the same type of collector gave efficiencies of collection of 74·4 per cent. and 30 per cent., respectively. In the case of the stoker-fired boiler 77·36 per cent. of the dust passing to the atmosphere was 60 microns or less, the corresponding figure for the pulverised-fuel boiler being 95·3 per cent. In the case of the stoker-fired boiler the concentration of dust passing to the atmosphere may be considered satisfactory. It may, nevertheless, cause a nuisance and a collector efficiency of not less than 88 per cent. should be aimed at. Dust arresters may be divided into the wet and dry types, the former being sub-divided into water spray, water film and combined spray and film, and the latter into Cyclones and electrostatic precipitators. The wet systems are relatively cheap to install and operate, provided that the effluent can be disposed of without costly filtration and chemical treatment. Their use is, however, open to the objection that the flue gases leaving the plant are reduced to very low temperatures and that chimney effect, as far as draught is concerned, is practically lost. The gas is also saturated and even supersaturated with water vapour, with the result that acid moisture particles may be deposited. Precautions must be taken to avoid corrosion and adequate supplies of water are necessary for the effluent system, which may require treatment and necessitate the use of settling tanks. The induced-draught fans must be situated on the dry-gas side to avoid corrosion, and as they therefore have to handle dust-laden gases they suffer from erosion. As regards the dry methods there is very little draught lost with electrostatic precipitators. On the other hand, with Cyclones, the draught loss is considerable, if a high efficiency is to be maintained. The efficiency increases and decreases in the case of the electrostatic and Cyclone precipitators, respectively, as the gas velocity falls. The space occupied by the electrostatic precipitator is large and the power consumption is low, the opposite being true for Cyclones. In both cases there is very little heat loss and the maintenance costs are low.

Electrostatic precipitators are installed on each of the boilers at Hams Hall, and are guaranteed to give an efficiency of 96·5 per cent. when a boiler is operating at maximum continuous rating (320,000 lb. of steam per hour) and with 4 grains per cubic foot of dust in the gases entering the arresters. It is obvious from the appearance of the gases leaving the chimneys (400 ft. high) that there is very little dust. What there is is 99 to 100 per cent. of 63-microns and less, and 75 to 95 per cent. of 20-microns and less. It is highly improbable that any dust of over 20-microns size leaves the chimney. The pressure drop across the filter chambers and ducting is only about 0·5 in. water gauge when the maximum continuous rating is on the boiler and carbon dioxide in the leaving gases is 13½ per cent. The precipitators are on the suction side of the induced-draught fans and hence handle clean gases.

Multiple Cyclones can to-day be obtained which will give, with dust from stoker-fired boilers, an efficiency of 90 per cent., with a reasonable draught loss and 95 per cent. with a draught loss of about 2·5 in. water gauge. In general, 90 per cent. efficiency may be considered high enough with stoker-fired boilers where the power station is well removed from residential areas. The efficiency of these multiple Cyclones for pulverised fuel-fired dust would be of the order of 90 per cent., with a draught loss of about 2·5 in. w.g., and if an attempt were made to obtain an efficiency of 95 per cent., the draught loss would be very considerable. Therefore, electrostatic precipitators have to be resorted to.

(*To be continued.*)

* Paper read before the annual convention of the Incorporated Municipal Electrical Association, at Bournemouth, on Tuesday, June 24. Abridged.

LABOUR NOTES.

ADDRESSING a meeting of the Workers' Educational Association in London last week, Sir Stafford Crippe, President of the Board of Trade, said that British workpeople must be trained at once to take up managerial or planning jobs in industry. Very few of these were at present fit for such posts, because in the past, they had had very little chance to learn. There had been, he went on, quite a lot of criticism among trade unionists of his supposed views on the question, due very largely to a complete misunderstanding of what he had said. He had never doubted the inherent capacity of the British worker to do any job, technical or managerial, administrative or planning, given the opportunity to learn it first.

But, he continued, management needed a high degree of training as well as the right outlook. The difficult was that whereas millions of employees had the technical experience, very few had had the different type of education needed to fit them to take part in the managerial, consultative and planning sides of industry. It was no criticism of the employees that that was so; it was a criticism of the slowness of our society, in the past, to give them the opportunity

The Railway Shopmen's National Council has accepted the report of the recent Court of Inquiry into the claims of the railwaymen's unions for wage increase and a shorter working week. It was agreed that the increase in pay of 7*s.* 6*d.* a week, and the 44-hour week, should operate as from June 30.

Mr. Isaacs, Minister of Labour and National Service, gave an outline, in the House of Commons last week, of the plans which the Government proposed to make with the object of spreading the industrial load on the country's electricity supply resources. There was no single way, he declared, of achieving the desired purpose, and various methods would have to be adopted. Day-shift hours could be adjusted so that some factories started after the morning peak and others ended before the afternoon peak; some factories could work staggered day shifts, others night shifts; rota schemes could be operated, and so on. There was also the question of the terms and conditions under which revised working hours could be operated and in respect of that the engineering industry's recent agreement gave a useful lead. He had invited the British Employers' Confederation and the Trades Union Congress to draw the attention of their constituent organisations to it, and he urged all industries to consider at once their own position in the matter.

The Government, Mr. Isaacs said, had laid upon the regional boards for industry and their district and other committees, the complicated but vital task of working out the plans to achieve the regional target of moving one-third of the peak load outside the normal day-time period. These bodies had already achieved substantial results, and he urgently appealed to industry to co-operate to the full in completing the schemes and reaching the target.

The possibility that there might be cases of unreasonable failure to operate approved schemes could not be disregarded, continued the Minister, and the Government had decided that compulsory powers must be used to deal with such cases. Once a case had been established, a direction would be issued under the Defence Regulations by the Minister of Fuel and Power, compelling the firm, under penalty, to reduce its maximum demand on the electricity supply to the required level. The regional board would have to satisfy itself that a case had been established, but before action was taken, each case would be further examined by the electricity sub-committee. The Minister of Fuel and Power would thus have the advice of both the regional board and the sub-committee when he issued a direction. In reply to a question, Mr. Isaac said that there was no proposal to close firms down.

At its meeting last week, the General Council of the Trades Union Congress accepted the engineering agreement on the subject of staggered hours and decided to circulate copies of it to the affiliated unions. There was also some discussion on Mr. Arthur Deakin's declaration at the conference of the Transport and General Workers' Union in favour of direction of labour, but there did not appear to be much solid support for the idea. Apart from the traditional hostility of organised employees to compulsion in any form, there was a feeling that the members of the affiliated unions would not stand for the proposal.

The National Joint Advisory Council to the Ministry of Labour and National Service—on which both the employers' organisations and the trade unions are represented—decided, on the suggestion of the General Council of the Trades Unions Congress, to ask the Cabinet frankly to make known the facts about Britain's approaching economic crisis and explain what they proposed to do in the matter. It did not discuss the question of direction of labour or that of higher wage rates and improved conditions with the object of attracting workers to the undermanned industries; but it adopted a resolution recommending that in all industries "joint consideration should be given to the desirability and practicability of introducing or extending systems of payment which provide the maximum incentive to increase output."

Later, the position may become clearer, but as these notes are being prepared, the trouble which threatens to involve the building industry is, to say the least, confused. A conference of the Amalgamated Union of Building Trade Workers at Worcester last week unanimously adopted a resolution calling for the ending of the Government's adult training scheme for building recruits. The number of bricklayer trainees already admitted was, it was declared, as many as could be efficiently employed. Earlier in the day, Mr. Isaacs, the Minister of Labour and National Service, had told the conference that the scheme was still necessary, though to what extent was a matter for discussion. Replying to questions afterwards, the Minister said that the Government had no desire to carry on the training scheme unless it had the co-operation of the union, and promised that trainees would not be used as cheap or semi-skilled labour.

The position in respect of the wages claim of the National Federation of Building Trades Operatives is no less obscure. According to a statement made earlier in the week, the employers had made an offer of 3*d.* an hour which was deemed by the unions to be inadequate. Subsequently, however, the National Federation of Building Trades Employers stated that they had made no offer of an increase of any kind in basic wages. The position at the moment was, they said, that the organisations of both employers and operatives were considering a suggestion on the subject by Mr. Isaacs. The suggestion was, it may be explained, that some incentive plan might be adopted with the object of increasing output.

In opening the conference of the Amalgamated Union of Building Trade Workers at Worcester, Mr. H. J. Adams, the President, said that we could only fully emerge from the present chaos by making building a public service. The conference adopted a resolution calling for a Government inquiry into the state of the industry, and also one—which the delegates accepted unanimously—urging the establishment of a State Corporation for the industry, and its early inclusion in any nationalisation programme.

Under an agreement to which the Agricultural Machinery and Tractor Owners' Association, the Amalgamated Engineering Union, the Transport and General Workers' Union, and the National Union of General and Municipal Workers are parties, the weekly working week is to be reduced from 48 hours to 45 hours. The change is to become effective in the first full pay week in August. The paid holiday provision, in addition, is to be amended; employees who are called upon to work on any of the Bank Holidays are to receive, besides double pay, a day in lieu with pay.

Reviewing the proceedings of the Labour Party conference at Margate, the writer of the editorial in the July issue of *The London Typographical Journal*, the organ of the London Society of Compositors, says: "Some of the speakers argued for a national wages policy; it was even suggested that the men and women elected to Parliament enjoyed the confidence of the people and were, therefore, best fitted to deal with the all-important question of wages. One would assume from such talk that there was complete ignorance of the highly complicated machinery of negotiation secured only after years of laborious struggle. . . Our politicians have enough to occupy them in dealing with the enormous programme of social legislation; let them get on with the job and leave the trade unions to deal with their own problems in their own way."

The Indian Advisory Planning Board recommended in a recent report that every effort should be made to remedy the great shortage of trained technical personnel. Engineering education should be expanded; equipment and courses in existing technical institutions should be overhauled and modernised; the scheme for sending students abroad now in operation should be given special attention; and action should be taken to train skilled craftsmen in engineering and other trades.

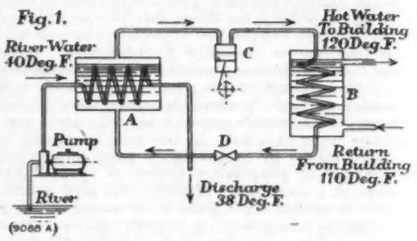
THE NORWICH HEAT PUMP.*

By J. A. SUMNER, M.I.Mech.E.

THE Nineteenth Century was notable for the practical and commercial development of the heat engine, which, in its turn, produced extensive scientific examination of the nature of heat and cold. Carnot propounded the cycle of operations of the ideal heat engine, and pointed out that the cycle was reversible, but showed that the reversed cycle could never be more efficient than the direct cycle of degrading heat so as to produce mechanical energy. Subsequently Dr. Joule, in 1851, suggested the use of a practicable engine working on the Joule cycle, and Bell-Coleman used an engine working on the reversed Joule cycle, to act as a refrigerator, with air as the working substance.

In 1852, attention was directed by Lord Kelvin to the fact that a refrigerator of the Bell-Coleman type could be used as a "warming machine," and that, given a supply of mechanical power, it was possible to expend this power so as to deliver heat without combustion. Further consideration of this reversed, or extended, refrigerating cycle, and of the meaning of "absolute cold" led to the conclusion that, given a supply of mechanical energy and a source of heat at such a low temperature as was formerly considered to be useless, it was possible, by using suitable apparatus, to obtain a heat output at a useful and higher temperature which could be several times greater than the heat equivalent of the mechanical energy used. Later, Ferranti and Perry considered the problem; but at that time the idea seemed to have no practical application, and it was not until 1929 that T. G. N. Haldane resuscitated it and pointed out that the widespread use of electric power, and the development of refrigerators, seemed to make

Fig. 1.



the heat pump (or a warming machine) practicable for certain conditions of use. Haldane designed and constructed a small experimental plant which was described by him in a paper which he read before the Institution of Electrical Engineers in 1930†. This paper aroused considerable interest, not only in this country but abroad, particularly in the United States and Switzerland, and led to several commercial installations being made in those countries, suitable for their special conditions of temperature.

So far as is known, no large commercial heat pump, designed purely for building-heating, and utilising low-grade heat from natural sources, had been constructed in this country until 1945, when the Norwich heat pump described in this paper was installed. It initiated a long-term experiment which was carried out on a larger scale than the previous experiments by Haldane. It is not desired to imply that the apparatus described herein, represents an example of high efficiency—the nature of the materials and plant available preclude it from being more than a relatively inefficient pump, constructed as a pioneer effort for practical use and experimental purposes; but it is hoped that the presentation of such factual data (probably the first to be made available in respect of heat pump operation in Great Britain) will provide a more reliable guide to the practicability and economy of use of the heat pump than the more hypothetical facts hitherto presented, which have been based upon conditions in other countries.

The heat pump is a refrigerating plant designed and constructed to work within limits of pressure and temperature, greater than those required for refrigerating purposes (the gas temperatures range from 30 deg. F. for T_2 to 200 deg. F. for T_1, as compared with 85 deg. F. for T_1 in the normal refrigerator). The main difference between a refrigerator and heat pump is that, whereas the former is used to extract from a body of air, or a substance in a cold room or chamber, heat which is normally discharged to waste, the heat pump extracts heat either from atmospheric air or from a supply of low-temperature water, such as a river or lake, and this heat, which is normally at too low a temperature to be useful, is then raised to a higher temperature by the

* Paper delivered at a meeting of the Institution of Mechanical Engineers held in London on March 28, 1947. Abridged.

† "The Heat Pump—An Economical Method of Producing Low-grade Heat from Electricity," by T. G. N. Haldane. *Jl.I.E.E.*, vol. 68, page 666 (1930).

THE NORWICH HEAT PUMP.

Fig. 2. SECTION XX

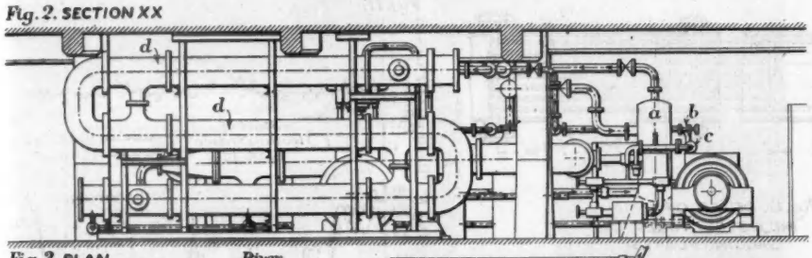
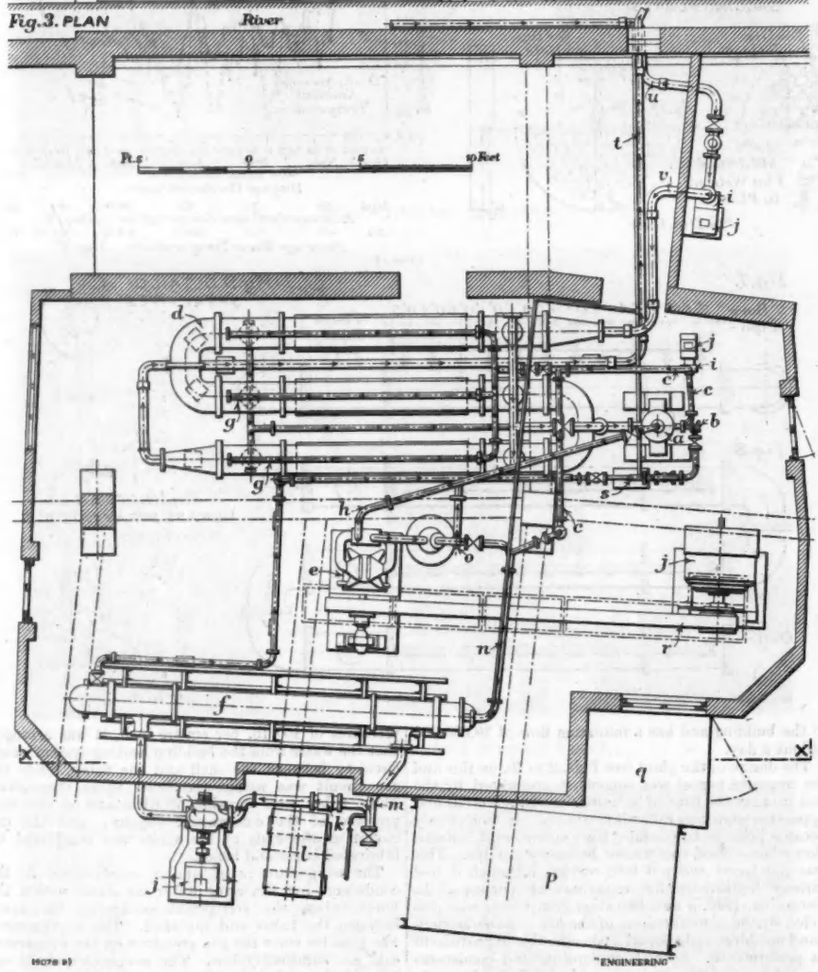


Fig. 3. PLAN



a Accumulator.
b ¼-in. charge valve for charging the system with sulphur dioxide.
c 2-in. liquid pipe.
d Evaporator.
e Compressor.
f Condenser.
g Spray pipes.
h 3-in. suction pipe.
i Pump.
j Motor.
k Heat and water meter.
l Electrode boiler.
m 4-in. hot-water pipe.
n 3-in. supply pipe.
o High-pressure safety valve.
p Storage tank.
q Electric control gear.
r Belt guard.
s High - pressure float valve.
t 4-in. water outlet pipe to river.
u 4-in. pipe from river to pump.
v 4-in. inlet pipe from pump.
w 4-in. suction pipe.

compressor. The heat at this higher temperature is used for the purpose of heating the building.

The advantage of the heat pump is that the heat put into the building may be three or more times the heat equivalent of the mechanical power required to operate the plant. The heat output really comes from two sources: (*a*) the low-grade heat supply (atmospheric air, river, well, or lake water, or mains water); and (*b*) the energy supplied to drive the plant (electrical, steam, Diesel engine, or water power). In a particular case, for example, for every 4 units of heat given out, approximately 3 units will be picked up from source (*a*), where it is usually available at no cost, and rather less than 1 unit is introduced as mechanical or electrical energy from source (*b*), which normally must be paid for. The ratio $\frac{\text{heat output}}{\text{energy input}}$—that is, $\frac{\text{sources (a) plus (b)}}{\text{source (b)}}$—is usually described as the coefficient of performance of the plant; a more suitable term, used throughout this paper, is suggested by the author, namely "reciprocal thermal efficiency."

Essentially, the heat pump comprises a cooler (evaporator) and heater (condenser), together with a compressor and an expansion valve, as shown diagrammatically in Fig. 1, opposite. In the closed circuit ACBD, a liquid refrigerant circulates; this may be ammonia, sulphur dioxide, or "Freon," etc. The compressor C reduces the pressure in the evaporator A to a level at which the liquid boils, the refrigerant chosen being one which will boil at a low temperature; sulphur dioxide will boil at 30 deg. F. under a pressure of 22 lb. per square inch absolute. In boiling, the latent heat of evaporation is taken from the low-temperature river water circulating in the tubes and is transferred to the refrigerant. The resulting sulphur-dioxide vapour is then compressed to a higher pressure, causing its temperature to rise. The hot vapour passes through the tubes of the condenser, condenses to a liquid, and so gives out to the building heating water, which is circulated round the tubes, its latent heat of condensation. The resulting liquid then passes through the expansion valve D (where its pressure is reduced) into the evaporator, and the cycle of operations is repeated.

In 1851, Kelvin stated that, if a heat engine has an absolute inlet temperature T_1 and an exhaust or refrigerator absolute temperature T_2, "the efficiency of a perfect heat engine is expressed by the ratio of the difference of the absolute temperatures of the source and condenser to the absolute temperature of the source." Thus, for an ideal engine, working directly so as to degrade heat and thus produce work, we have the well-known expression

$$\text{thermal efficiency } E = \frac{\text{work produced}}{\text{heat taken in at high temperature}} = \frac{T_1 - T_2}{T_1};$$

that is, assuming working terminal temperatures T_1 = 180 deg. F. (640 deg. F. abs.), and T_2 = 80 deg. F. (540 deg. F. abs.),

$$E = \frac{640 - 540}{640} = 0{\cdot}156, \text{ or } 15{\cdot}6 \text{ per cent.} \quad (1)$$

This means that, of the total heat energy originally available, 15·6 per cent. has been converted into mechanical work, and 84·4 per cent. has been rejected. What happens if the cycle of operations of the above heat engine is reversed, so that, instead of supplying heat at high temperature and rejecting the residue at low temperature after work has been done, we take in heat at low temperature, do work on it, and thereby complete the cycle so as to obtain heat at a higher temperature? Obviously, if such an exactly reversed cycle of operations can be performed, the reciprocal of the above expression will be obtained; *i.e.* (for the ideal engine)

$$\frac{1}{E} = \frac{\text{heat produced (at high temperature)}}{\text{work expended}} = \frac{T_1}{T_1 - T_2}$$

$$= \frac{640}{640 - 540} = 6{\cdot}4 \left(\textit{i.e.}, \frac{1}{0{\cdot}156} \right) \text{ or } 640 \text{ per cent.} \quad (2)$$

This would mean that a quantity of heat has been taken in and raised from a low temperature so as to be delivered at a higher temperature, the heat delivered being 6·4 times greater than the heat equivalent of the mechanical or electrical energy expended to carry out the operation. It will be noted that heat has not been "created." Almost the same quantity of heat that has been delivered at a high and commercially useful temperature was available originally at a low temperature which had no commercial value. The function of the heat pump, and of the electrical or mechanical energy used to drive it, is merely to lift the temperature of available heat from the lower to the higher temperature. It will be seen that the coefficient adopted for the heat pump operation is one designed to measure the ratio of high-temperature heat delivered to the work expended to carry out the operation. The coefficient is also seen to be the reciprocal of the expression used to ascertain the thermal efficiency of the direct heat engine.

It would seem to be important to differentiate between the operation of the refrigerator and that of the heat pump. While, in each case, we are considering a heat pump as a pump driven by mechanical means, so as to pump up heat from a low to a high temperature, in the latter case the operation has been extended to a considerable degree. The most efficient refrigerator is the one which abstracts the greatest amount of heat from the cold body for a given expenditure of mechanical work. The standard method of defining this ratio for the refrigerator is as follows:—

$$\frac{\text{heat abstracted}}{\text{work expended}} = \frac{T_2}{T_1 - T_2} = \text{coefficient of performance};$$

but the most efficient heat pump will be the one which delivers the greatest amount of heat at high temperature, and the method of defining this ratio for the heat pump is as follows:—

$$\frac{\text{heat delivered}}{\text{work expended}} = \frac{T_1}{T_1 - T_2}.$$

Thus, the expressions which define the most efficient machine—for a refrigerator and heat pump, respectively,—have entirely different meanings numerically and in their connotations. The heat-pump cycle is, literally, the reversed operation of the cycle used in the heat engine as defined above by Kelvin, and the expression for their respective efficiencies of operation are reciprocal. It is suggested, therefore, that the term "coefficient of performance" should be restricted to the operation of the refrigerator. When considering the operation of the heat pump—which, ideally, is the reversed heat-engine cycle—it is suggested that the

THE NORWICH HEAT PUMP.

Fig. 4.

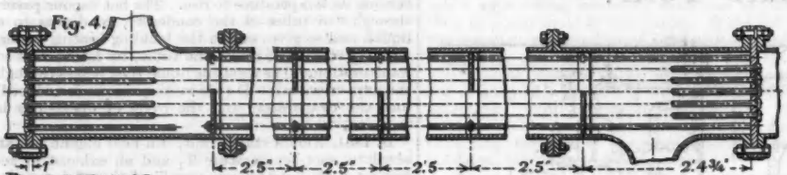
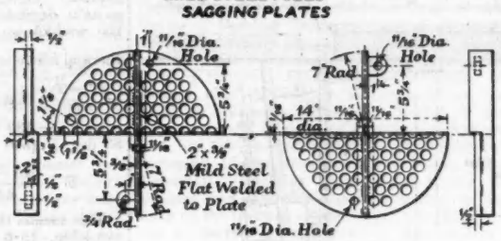


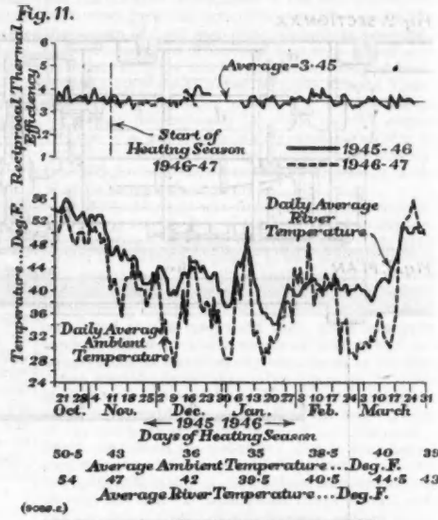
Fig. 5. DETAIL OF BRASS TUBE PLATES

Fig. 6. DETAIL OF MILD STEEL TUBES SAGGING PLATES



(scale c)

Fig. 11.



(scale e)

term "reciprocal thermal efficiency" should be used (see equations (1) and (2) above), and this term has been used throughout the paper.

In 1940 the new workshops and offices of the Norwich Corporation Electricity Department were nearing completion, and it became necessary to decide upon the type of plant to be installed for heating the building. The central-heating installation had already been erected. A specification for a heat pump was forwarded to each of the British manufacturers of refrigerating plant with a request that they should tender for the supply of a heat-pump installation. No manufacturer was prepared to submit a tender. It was noteworthy that all (with one exception) were sceptical as to the economy or possibility of using a heat pump for building heating in this country.

It was decided temporarily to install modern coal-fired boilers, with accurate meters for measuring continuously the heat put into the building (and thereby the true combustion efficiency); to make a long-term scientific test relating to the costs and other features associated with the coal-fired boilers; and, subsequently, to install a heat pump in place of the boilers, so that the true comparative costs of building heating by these various methods could be established. It was not until 1944-5 that the opportunity occurred to install a heat pump in substitution for the boilers. Even then, it became necessary to construct this heat pump by using an old second-hand compressor and to manufacture the evaporator, compressor, and most of the other components from materials available in the distribution and power-station stores.

The Norwich heat pump, therefore, has not the somewhat higher efficiency that would be associated with a modern machine, constructed under better conditions. It has, however, permitted accurate data to be established as to the relative costs of heating a large building by coal-fired boilers and by the heat pump, respectively. Primarily it has been possible to demonstrate that normal British conditions are such as to permit even a relatively inefficient machine to operate satisfactorily for heating a building throughout a normal British winter, and to operate with considerable economy in fuel consumption.

The building is of steel and reinforced concrete, brick filled, with very large window area. There is a hot-water central-heating system, comprising wall radiators, embedded panel heaters, and (originally) "unit" heaters with electric fans. The system was designed for a flow temperature of 180 deg. F. to 16 deg. F. During the winter of 1940-1, experiments were carried out to ascertain the minimum flow temperature required to maintain a temperature of 62·5 deg. F. in the offices and 60 deg. F. in the workshops, on the coldest days. It was found that, provided the "unit" fan heaters were not used, the maximum flow temperature required was 130 deg. F. during the short periods of very low ambient temperature, but that 120 deg. F. would suffice as a maximum flow temperature for the major part of the heating season. In view of the high maintenance costs, and the unduly high flow temperatures required, the "unit" fan heaters were, therefore, replaced by radiators.

From 1940 to 1945, the coal-fired boilers were used exclusively. In October 1945, the Norwich heat pump was completed, and was put into use for the remainder of the heating season. The source of low-grade heat was the River Wensum, which is immediately adjacent to the building and has a minimum flow of 30,000,000 gallons a day.

Fig. 7.

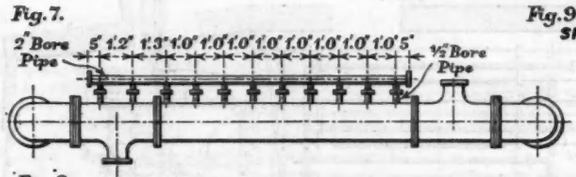
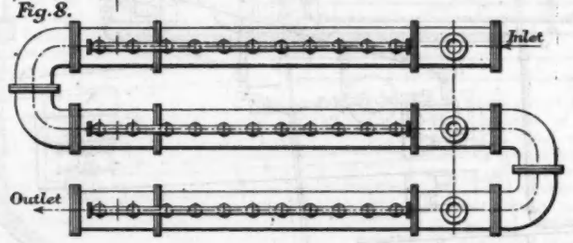


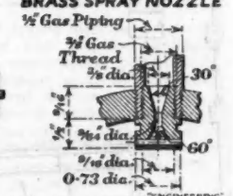
Fig. 8.



(scale d)

Fig. 9. DETAIL OF SPRAY PIPES

Fig. 10. DETAIL OF BRASS SPRAY NOZZLE



"ENGINEERING"

The design of the plant (see Figs. 2 to 10, on this and the opposite pages) was somewhat prejudiced by the fact that, at the time of its construction, materials and apparatus were very difficult to obtain. In fact, it only became possible to consider the experimental installation when a used compressor became available. This was purchased and put into service, although it had serious limitations for experimental purposes. In December, 1946, a new two-stage compressor was provided by the manufacturers of the less suitable second-hand machine, and showed a considerable improvement in performance. Special evaporators and condensers were also out of the question, and had to be made on site from such materials as were available. The only apparatus which was obtained from the refrigerator manufacturers was the automatic float valve and the safety valves. Figs. 12, 13 and 14, opposite, are views of the plant.

The first compressor, obtained second-hand, was manufactured about 25 years ago by Messrs. Peter Brotherhood, Limited, of Peterborough. It was a single-stage double-acting machine, bore 11 in., stroke 9 in., maximum speed 350 r.p.m., and was designed for use with ammonia. The output, when used for ice making, was stated to be 16 tons in 24 hours.

The second compressor was of the single-crank two-stage annulus type. Cylinder bore: first stage 16 in.; second stage, annulus 16 in. minus 13¼ in. Stroke 9 in. Speed 300 r.p.m.

The condenser is of the shell and tube type, the shell being made of standard cast-iron flanged water pipes. The necessary connections were made by using suitable T-pieces. There are three shells mounted one above the other, and each consists of two T-pieces with a straight section between them. At the extreme ends a tube plate is fitted, and standard brass turbine condenser tubes are jointed to the tube plates by ferrules with metallic and fibre packings. The tube plates A (Fig. 5) were fitted to condenser bodies, and B to the evaporator bodies. Since the cast-iron pipes were only safe up to pressures of 100 lb. per square inch, it was arranged that the water from the building heating system would circulate between the shell and the tubes, while the gas circuit was within the brass tubes themselves. These tubes were capable of withstanding the high pressure of the compressed vapour; and the gas circuit at the ends of the shells was completed by fabricated boxes and bends.

The evaporator is of similar construction to the condenser, but the river water circulates within the brass tubes, the refrigerant occupying the space between the tubes and the shell. This arrangement was possible since the gas pressures on the evaporator side are sufficiently low. The evaporator shells are pierced along their length to permit the insertion of spray nozzles through which the liquid refrigerant is pumped in the form of a fine atomised spray over the water tubes. The object of this was chiefly to reduce the amount of refrigerant in the plant, but it was also thought that the use of sprays might assist evaporation.

The liquid-circulation pump was of the standard centrifugal type, driven by a 3-h.p. three-phase motor. It was fitted with a "packless" gland to make it suitable for use with the refrigerant. The liquid receiver was fabricated from steel sheet. All the pipework for the refrigerant circuits was carried out in high-pressure mild-steel tubing, and that for the water circuits in similar piping of suitable grade. Standard steam and water valves were used. The automatic float valve is of the standard ammonia type, incorporating a float chamber with a by-pass needle valve and the necessary isolating valves. The safety valves were of the spring-loaded type commonly used on refrigerating plant.

As it was intended to run the plant unattended for considerable periods, automatic safety devices, arranged to trip the driving motor, were devised and fitted. They gave protection against excessive pressure in the condenser, displacement of the belt on the compressor flywheel, failure of the river-water circulating pump, excessively low pressure in the evaporator, and blockage of filters in the river-water circuit or blockage of evaporator tubes.

THE NORWICH HEAT PUMP.

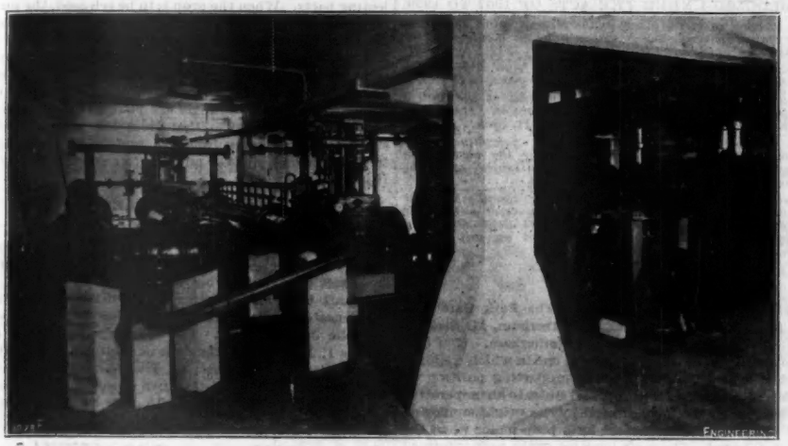


FIG. 12. EVAPORATOR AND CONDENSER.

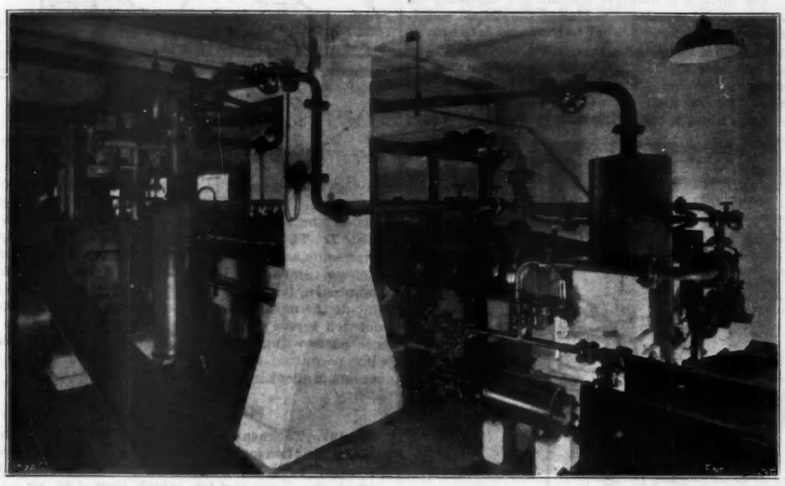


FIG. 13. LIQUID RECEIVER AND EXPANSION VALVE.

FIG. 14. COMPRESSOR AND EVAPORATOR.

The choice of refrigerant was largely governed by mechanical considerations and availability. The compressor bearings limited the permissible pressures to 200 lb. per square inch; consequently, ammonia was out of the question for the output temperatures required. Freon 12 was not obtainable, and finally it was decided to use sulphur dioxide. This refrigerant allowed the use of brass condenser tubes, which would not have been possible with ammonia.

The results of operation during the winter of 1945-6 and 1946-7 are shown in Fig. 11, opposite. During November, 1945, trouble developed due to solid bodies being drawn in from the river into the evaporator tubes, thus causing water restrictions and freezing within the tubes. The latter trouble was overcome by installing a gauze screen on the river-water inlet pipe and by fitting a safety device to trip the driving motor if the velocity of the river water in the tubes fell below a certain value. The cessation of operation in December, 1946, is due to the installation of the new compressor. It will be seen that the averaged seasonal efficiency obtained with the old compressor during the winter heating season 1945-6 is 3·45. The installation of the new compressor resulted in a still greater efficiency of operation. The results tend to show that the heat pump of the immediate future, with design based upon experience, should be able to work in Great Britain at an average seasonal efficiency of the order of 4, with water and ambient-air conditions as for the Norwich experiment.

It has been mentioned that the experiment embodied a careful scientific study of the costs of heating a given building by means of coal-fired boilers and a heat pump, respectively. Expenditure to provide thermal storage can usually be fully justified when the heat pump is electrically driven, so as to obtain the benefit of off-peak charges. The following Tables I and II allow for the introduction of thermal storage, so as to illustrate this point.

TABLE I. *Comparative Annual Operating Data.*

Heat supplied to building during heating season	20,000 therms
Peak heat demand	8 therms
Average heating demand	5 therms
Calorific value of coal (¾-in. washed nuts)	12,000 B.Th.U. per lb.
Price of coal per ton	65*s.*
Cost of electricity :—	
For loads on peak	4*d.* per kVA plus 0·6*d.* per kWh
For loads off peak	0·6*d.* per kWh
Average thermal efficiency of combustion	55 per cent.
Average seasonal cost of attendance, removing ashes, filling hoppers, etc., on coal-fired boilers	230*l.*
Averaged annual cost of maintenance and repair of coal-fired boilers	150*l.*
Capital cost of coal-fired boilers	1,500*l.*
Capital cost of heat pump	3,000*l.*
Additional cost of thermal storage vessel for heat pump	500*l.*

The comparative costs (based upon facts derived from a long-term experiment) of heating a building of 500,000 cub. ft. are shown in the first two columns of Table II. The case relating to thermal storage

TABLE II. *Comparative Annual Costs of Heating a Large Building.*

	Coal-fired boilers.	Heat pump.	
		Without thermal storage.	With thermal storage.
Capital cost	1,500*l.*	3,000*l.*	3,500*l.*
Averaged seasonal reciprocal efficiency	—	4·00	4·00
Tariff for electrical energy	—	4*d.* per kVA demand; 0·6*d.* per kWh.	0·6*d.* per kWh.
Annual capital charges	225*l.* (15 per cent.)	210*l.* (7 per cent.)	245 (7 per cent.)
Cost of coal (or electricity)	440*l.*	601*l.*	367*l.*
Annual cost of attendance	230*l.* (including coal and ash handling)	—	—
Repairs and maintenance	150*l.*	50*l.*	50*l.*
Replenishment of refrigerant	—	25*l.*	25*l.*
Total	1,045*l.*	978*l.*	769*l.*
Cost per therm	12·5*d.*	11·7*d.*	9·2*d.*

is not a part of the actual experiment. On a purely financial basis, the heat pump is shown to be the cheapest method of heating a building in England with characteristics as described; but the national consideration of the most suitable form of heating to adopt involves considerations other than those of finance; for example, economy in the use of coal, a substance which may prove to be a rapidly wasting asset.

To drive the electric motor for the more efficient heat pump, with a reciprocal efficiency of 4, involves burning at the power station 9·1 lb. of low-grade coal for each unit of heat (therm) passed into the building. To pass a unit of heat (therm) into the building when the coal-fired boilers were used requires 16·6 lb. of a much better quality coal. Thus, if this instance is assumed to apply to the general case, in place of each 1,000,000 tons of high-grade fuel burned annually on direct heating boilers for building heating, only 545,000 tons of much lower-grade fuel would be required at the generating stations if it were possible to replace the heating boilers

by heat pumps. To the consequential national advantage can be added further benefits in the form of reduced smoke emission, and the reduced production and transport of ashes, etc., would be even greater. From a national standpoint, the saving of coal which the heat pump would effect may be more important than the saving in monetary costs.

NOTES ON NEW BOOKS.

Serving a Nation at War, 1939-1945. John Laing and Son, Limited, Bunn's-lane, London, N.W.7.

IT is stated by Messrs. John Laing and Son that during the first four years of the war, the building and civil-engineering work carried out by them represented one five hundredth part of the total national effort, measured in monetary value. Included in the national effort is the total cost of the Navy, Army and Air Force and all manufacturing and construction for the Government. In view of the vast total sum which these items represent, the firm's claim is a remarkable one, but its justification will be understood from an examination of the book bearing the above title which has recently been published. It is a handsome, lavishly illustrated volume, in which some of the firm's main war activities are dealt with in broad outline. First place is given to the headquarters of the R.A.F. Bomber Command. This involved the construction of more than 60 separate buildings as well as the underground operations block. Although the labour force never exceeded 400 men, the headquarters was handed over to the Royal Air Force in March, 1940. The ability in organisation which this piece of work represented was applied in a very wide field and the book deals with some of the many factories, power stations and airports constructed by the firm. In addition to the Royal Ordnance Factories built, which included the Sellafield factory in Cumberland in which the building and civil engineering work carried out by the firm amounted to 1¼ million pounds, no less than 50 factories for light industries were built in the London area alone. A total of 54 large airports was constructed and the book gives brief details of soil-compaction and drainage methods applied. An entirely different class of work in which the firm became involved was the winning of opencast coal, while constructional work was further represented by the building of 10 of the largest concrete caissons and 40 of the floating pontoons for Mulberry Harbour. A feature which will strike many readers of this interesting volume is the pleasing appearance of the majority of the industrial buildings which the activities of Messrs. Laing added to the capital equipment of the country during the war.

Machine Shop Operation. By LEWIS E. KING, M.S. 1. *Lathe Operations*. 2. *Milling Machine Operations*. The Macmillan Company, 60-62, Fifth-avenue, New York City, U.S.A. [Price, each, 1.80 dols.] Macmillan and Company, Limited, St. Martin's-street, London, W.C.2. [Price, each, 9*s*. net.] 3. *Shaper Operations*. [Price 1.0 dol., or 5*s*., net.]

THESE books, intended for engineering students setting out on a course of workshop training, should be helpful also to the younger operatives who may wish to extend their knowledge of machine-tool work. Mr. King is an experienced toolmaker who has spent several years in teaching machine-shop practice at the high schools and trade schools of Detroit, and is well qualified to approach his subject from both a practical and theoretical standpoint. The first book, *Lathe Operations*, deals with the general-purpose back-geared screw-cutting lathe, the fundamental principles involved in its operation, and the cutting tools generally used; no other type of lathe is considered, but the reader who has mastered the type described will be well on the way towards a working knowledge of others. The grinding of lathe cutting-tools is discussed, but no mention is made of negative-rake tools. The author covers the usual field—speed, feed and depth of cut, methods of holding the work, facing and centring work, straight turning between centres, form turning, knurling and taper work, etc., as well as screw cutting, drilling, boring, reaming, and other operations. The second book, *Milling Machine Operations*, deals similarly with horizontal and vertical milling machines, and the uses of their various attachments. The ground covered includes, besides plain and end milling, some reference to form milling, angular milling, and spiral and helical milling. Tables of Brown and Sharpe, Morse, and Milling Machine Standard Tapers are also appended, together with a selection of useful rules and formulæ. The third book, *Shaper Operations*, is generally similar in character to the others. It deals with the shaping of horizontal, vertical and irregular surfaces, angular surfaces, dovetails, slots, keyways, etc. It is not necessary to be a mathematician to understand Mr. King's books; he deals with his subjects in a plain and straightforward manner, and is liberal with his illustrations.

"ENGINEERING" ILLUSTRATED PATENT RECORD.

ABSTRACTS OF SPECIFICATIONS RECENTLY PUBLISHED UNDER THE ACTS OF 1907 TO 1939.

The number of views given in the Specification Drawings is stated in each case; where none is mentioned, the Specification is not illustrated.

Where inventions are communicated from abroad, the Names, etc., of the Communicators are given in italics.

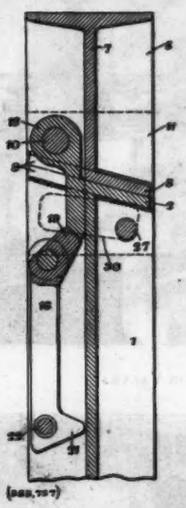
Copies of Specifications may be obtained at the Patent Office Sales Branch, 25, Southampton Buildings, Chancery-lane, London, W.C.2, price 1s. each.

The date of the advertisement of the acceptance of a Complete Specification is given after the abstract in each case, unless the Patent has been sealed, when the word "Sealed" is appended.

Any person may, at any time within two months from the date of the advertisement of the acceptance of a Complete Specification, give notice at the Patent Office of opposition to the grant of a Patent on any of the grounds mentioned in the Acts.

MINING.

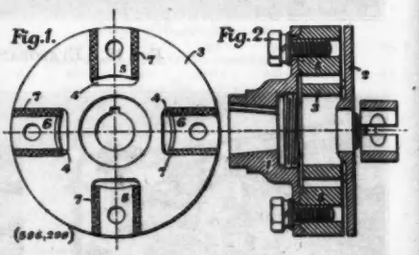
585,757. Collapsible Pit Prop. The Park Gate Iron and Steel Company, Limited, of Rotherham, M. Beckett, of Rotherham, and A. Craig, of Rotherham. (7 *Figs.*) October 28, 1944.—The pit prop is one in which a sliding head is locked in the operative supporting position on to the main length of the prop, and slides to an inoperative position under the force exerted by the weight supported and by being drawn forward by a prop-puller when the lock is released. The main length 1 of the prop is formed of H-section rolled-steel joist cut at the top at a flat angle to receive a stout plate 2 welded to the flanges and web. The head 5 is made of the same H-section with its flanges carried round and welded to the shaped web 7. At the bottom, the head 5 is cut to the same flat angle as the main length 1 and has a stout plate 8 welded to the flanges and web 7. The head forms a continuation of the main length and is of the same standard material. On the outside of the prop, wide notches 9 are cut out of the plates 2 and 8, extending back to the webs. Above



the notch in the head, a pivot pin 10 passes through the flanges and extends into two side cheeks 11 of flat plate welded to the flanges. The cheeks 11 prevent lateral tilting or sliding of the head 5. A locking lever 13 is pivoted on the pin 10 and has clearance in the slots 9, so that its wide tongue can hang down and bear against an abutment formed by the upper end of the web of the main length 1 and the end of the slot in the plate 2. When in this position, the tongue is held by the nose 19 of a lever 16 pivoted on a transverse pin passing into the flanges of the length 1. The lever 16 is held in position by a loose pin 22 passing through holes in the flanges and a hole in the lever. A chain anchors the pin 22 to the prop. On the inside of the main length 1, and close to the plate 2, a pin 27 passes through the flanges and is secured by split pins with its ends entering slots 30 formed in the portions of the cheeks 11 projecting below the head 5. The head can pivot loosely about the pin, but remains attached to the main length 1. In use, the head 5 is aligned with the main length and the locking lever 13 is held by the nose 19 of the lever 16. The tongue of the lever 13 is inclined where it is engaged by the nose 19. Any attempt to rotate the lever 16 anti-clockwise about its pin is prevented by the projection 21 engaging the web. The lever 16 does not depend on the pin 22, the latter being provided only to prevent accidental release of the catch. The head 5 is locked to the main length 1, and sliding of the plate 8 on the plate 2 cannot take place. The force exerted by the lever 16 on the locking lever 13 reacts between the pin 27 and the lower edge of the right-hand end of the slots, thus preventing anti-clockwise tilting of the head 5. The prop can be placed in position as if it were a solid prop, and is generally very easy to handle and use, because of its smooth construction, substantially free from projecting parts. When the prop is to be released, the pin 22 is withdrawn from the lever 16, and the latter is rotated clockwise to withdraw the nose below the tongue of the locking lever. As the prop is drawn forward by a prop-puller, the locking lever 13 is thrown clockwise about its pin 10, the tongue passing the lever 16, and the head 5 is free to slide on the plate 2, thus producing a contraction in length that frees the prop, notwithstanding the pressure from the roof, until the head is free to turn loosely on the pin 27. (*Accepted February 24, 1947.*)

MOTOR VEHICLES.

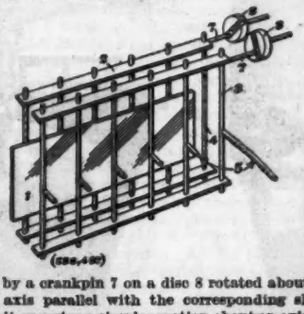
586,298. Shaft Couplings. Lagonda Limited, of Staines, Middlesex, and G. W. A. Green, of Staines, Middlesex. (3 *Figs.*) October 30, 1944.—The invention is a shaft coupling driving a fuel-injection pump of the camshaft type on an internal-combustion engine, and compensates for errors of alignment between the driving and the driven shafts. The coupling consists of two flanges 1, 2 (Fig. 2) on the ends of the two shafts and an intermediate floating disc 3. The disc has four radial slots (Fig. 1) accommodating two diametrically-opposed pairs of driving dogs 5 and 6 with considerable clearance.



The dogs 5 are screwed to the flange 1 and the dogs 6 to the flange 2. Sandwiched between the dogs and the side walls of the slots and bonded to both, are layers of rubber 7. The drive is transmitted by means of direct compression and tension in the rubber sandwich layers 7 which are comparatively stiff as regards yielding in direct compression, but if the axes of the coupled shafts do not coincide the misalignment is taken care of by the rubber sandwich layers yielding in shear. Since there are no loose parts within the coupling, all relative movement being permitted by the bonded sandwich layers, the coupling is silent in operation. (*Sealed.*)

MISCELLANEOUS.

586,497. Toughening Glass Sheets. British Indestructo Glass, Ltd., of London, and A. Tillyer, of London. (3 *Figs.*) November 23, 1944.—The invention is an improved method of moving the jets which blow cold air on to both sides of a heated glass sheet for the purpose of toughening it. The glass sheet 1 is heated to the required temperature and passed between two opposed vertical grids 2 and 3 of perforated pipes 4 which are supplied with air under pressure by flexible tubes 5. The perforations are directed towards each other so that the air jets from the perforations are at right angles to the faces of the sheet 1. The perforations in the two grids correspond exactly with one another. Each grid is



driven by a crankpin 7 on a disc 8 rotated about a horizontal axis parallel with the corresponding sheet-face so that it executes a circular motion about an axis parallel with that of the disc, the air jets being brought near to and farther from the glass sheet as they are moved up and down in a vertical plane. The movements of the grids are synchronised so that they both move towards the sheet 1 and both move upwards at the same time. For adjustment of the minimum spacing between the grids 2 and 3, the discs are mounted so that they may be moved towards and away from each other as required, and the amplitude of the motion of the grids is adjustable by varying the positions of the crankpins 7 along the diameters of their discs. (*Sealed.*)